FC

Report No. FAA-RD 75-80, III

(12)

A STUDY OF THE COMMUNICATIONS REQUIREMENTS FOR A 1985 TO 2000 OPERATIONAL AERONAUTICAL SATELLITE SYSTEM

VOLUME III - EXAMINATION OF SELECTED OPERATIONAL ISSUES FOR AEROSAT EVALUATION

Danny E. Cornett   J. Kent Haspert

MARCH 1976

FINAL REPORT

Document is available to the public through the
National Technical Information Service,
Springfield, Virginia 22151

Prepared for

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research and Development Service
Washington, D. C. 20590

NOTICE

Technical Report Documentation Page

(19)

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
(18) FAA-RD-75-80[redacted]		

4. Title and Subtitle	5. Report Date
(6) A STUDY OF THE COMMUNICATIONS REQUIREMENTS FOR A 1985-2000 OPERATIONAL AERONAUTICAL SATELLITE SYSTEM. VOLUME III. EXAMINATION OF SELECTED OPERATIONAL ISSUES FOR AEROSAT EVALUATION.	(11) Mar[redacted]76
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
(10) Danny E. Cornett, J. Kent Haspert	(14) 1307-01-1-1401 -Vol-3

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
ARINC Research Corporation A Subsidiary of Aeronautical Radio, Inc. 2551 Riva Road Annapolis, Maryland 21401	
	11. Contract or Grant No.
	(15) DOT-FA75WA-3544

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Department of Transportation Federal Aviation Administration Systems Research & Development Service Washington, D.C. 20590	Final Report, Phase II Tasks 1, 2, and 3
	14. Sponsoring Agency Code
	(12) 87p.

15. Supplementary Notes

(9) Final rept. on Phase 2,

16. Abstract

This study has been conducted to support an ongoing effort to define the scope of the test planning required to execute the AEROSAT Test and Evaluation (T&E) Program. It consisted of three areas of examination: (1) Selection of viable operational concepts for evaluation, (2) Capabilities and potential uses of a Mini-ASET and (3) Potential use of an AEROSAT during off-peak periods. Seven basic operational concepts and two expanded uses for an AEROSAT system have been developed to describe the alternative communications services, operating modes, and message types and characteristics that should be considered for evaluation during the T&E program. While the findings are preliminary in nature, the study has identified and begun to clarify a number of issues including: fundamental combinations of services, modes and message types that should be included in the program; technical and operational factors associated with the selection of a preferred concept; reasons for considering Mini-ASET and off-peak services concepts, capabilities and applications of a Mini-ASET concept; application and implementation of an off-peak services concept; problem associated with the Mini-ASET and off-peak services concepts; and operational tests to be conducted during the T&E Program.

Earlier work regarding communications requirements for a 1985-to-2000 operational aeronautical satellite system (Volumes I and II of this report) served as the basis for the current study.

17. Key Words	18. Distribution Statement
Satellite Communications, AEROSAT Test and Evaluation Program, AEROSAT Test Planning, Operational Concept Evaluation	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	87	

A

400 247

METRIC CONVERSION FACTORS

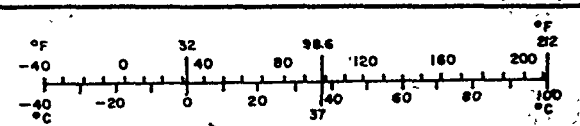
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10 286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



SUMMARY

1. BACKGROUND AND OBJECTIVES

The general objective of this study was to support the Federal Aviation Administration's (FAA) ongoing effort to define the scope of the test planning required to execute the Aeronautical Satellite (AEROSAT) Test and Evaluation (T&E) Program. During the study several communications concepts that should be considered for evaluation during the T&E Program were defined. As would be expected at this stage of a large and complex international program, it was necessary to consider a wide range of conventional and unconventional system applications, and its finding are, therefore, of a preliminary nature.

The specific objectives of the study were to: (1) select a practical set of basic operational concepts for evaluation; (2) characterize the capabilities and potential uses of a small earth terminal known as a Mini-ASET; and (3) investigate potential uses of an aeronautical satellite system during off-peak periods.

From the outset it was recognized that continuing reinvestigations throughout the test planning stage would be required, and that the goal of this initial investigation was to identify and begin to clarify the issues associated with the AEROSAT test program. Earlier work done for the FAA with regard to communications requirements for a 1985-2000 operational aeronautical satellite system (Volumes I and II of this report) served as a basis for the current effort.

2. STUDY ACTIVITIES

The work effort was divided into three task areas: basic operational concepts, the Mini-ASET concept, and the off-peak services concept. The approach to each task was twofold. First, an examination of the technical considerations associated with the implementation and operation of each concept was performed. Then, present and projected operational conditions were reviewed to determine how each concept might be utilized and to identify conditions that might affect the implementation of these concepts.

3. SUMMARY OF RESULTS AND CONCLUSIONS

Seven basic concepts and two expanded uses for an AEROSAT have been developed to describe the alternative communications services, operating modes and message types and characteristics that should be evaluated during the T&E Program.

The seven basic concepts describe a number of possible methods for conducting conventional aeronautical mobile satellite communications. The air-ground-air communications services offered by these concepts range from voice-only communications with voice position reporting to voice and data communications with dependent and independent surveillance. The operating modes associated with these concepts range from a manual access-control system that calls for the use of channels on a contention basis to a fully automatic and ordered access-control system. Together, these concepts suggest the more important areas for operational evaluation during the T&E Program. Particular technical and operational factors and suggested tests associated with the implementation and evaluation of these concepts have been addressed in the study.

The two expanded uses for an AEROSAT--the Mini-ASET concept and the off-peak services concept--are discussed to illustrate unconventional methods of utilizing an aeronautical satellite system. The Mini-ASET concept discussion presents two means of providing communications access to a satellite system in areas where it is undesirable, impractical or impossible to use conventional communication facilities. In one case, the Mini-ASET communicates with aircraft by means of direct satellite relays. In the other, indirect relays via an Aeronautical Satellite Communications Center are employed to provide the communications links between Mini-ASETS and aircraft. Unfortunately, only the second of these methods is suitable for direct testing during the T&E program. A simulated configuration is suggested as an indirect means for evaluating the first method. The application of these configurations for air traffic control, search and rescue and company operational purposes is then explained. At the conclusion of the examination of this concept, some of the tests that should be conducted to demonstrate the use of the Mini-ASET were identified.

During periods of low air-ground-air communications activity, the satellite system could potentially support additional types of communications. The off-peak services concept presented herein would permit the transfer of information between ground users and aircraft and among ground users in a manner that would not jeopardize the system's primary purpose of providing aeronautical mobile communications services. The potential services that could be offered through the implementation of this concept, the complex problems that would have to be solved if its implementation is to be permitted, and the tests that should be conducted to determine the merits of this concept have been addressed in this study.

4. RECOMMENDATIONS

The following recommendations have been offered:

- The FAA should proceed to define and approve a reasonable and well-organized, but limited, set of practical operational concepts for long-term evaluation.
- Research beyond that conducted in this study should be conducted to provide definitive results on the most desirable specific applications of the Mini-ASET.
- Investigation should be undertaken early in the T&E Program to determine, in more quantitative terms, the potential for and desirability of the implementation of an off-peak services concept.
- An effort should be initiated to develop the technical groundwork for making interconnect arrangements with existing aviation-related networks so that the technical and operational aspects of the off-peak services concept can be evaluated during the T&E Program.

CONTENTS

CONTENTS (Continued)

CHAPTER ONE

INTRODUCTION

In accordance with an international Memorandum of Understanding (MOU)*, the Federal Aviation Administration (FAA) has embarked upon a program of test and evaluation of satellite-based systems providing aeronautical communications services over oceanic areas. The first stage of this program is the development of a coordinated test plan. As part of the initial work that must go into defining the scope of the test-planning effort, the FAA requested that ARINC Research Corporation, in cooperation with airline representatives, explore and make comments on several aspects of operational testing. This document contains the results of these examinations of selected operational issues that will be an integral part of the AEROSAT Test and Evaluation (T&E) program.

1.1 STUDY OBJECTIVES

The issues examined in this study consisted of the selection of viable operational concepts for evaluation, the capabilities and potential uses of a Mini-ASET, and the potential use of an AEROSAT during off-peak periods. The objectives of the study were as follows:

- To review and further define alternative communications services, operating modes, and message types and characteristics (the primary components of an operational concept) that should be evaluated.
- To examine and characterize the capabilities and potential uses of Mini-ASETs and identify test conditions that should be evaluated.
- To review present communications associated with, but not technically defined as, aeronautical mobile communications; and to determine the related uses and restrictions of an aeronautical satellite during off-peak service periods that should be evaluated.

---

*Memorandum of Understanding On A Joint Program of Experimentation and Evaluation Using An Aeronautical Satellite Capability Between the United States Department of Transportation Federal Aviation Administration, The European Space Research Organization (ESRO), and the Government of Canada, August 1974.

From the outset, it was recognized that the full achievement of these objectives would require continuing reinvestigation throughout the test planning stage, and the goal of this initial investigation was to identify and begin to clarify these issues.

The study represents an outgrowth of earlier work done for the FAA with regard to communications requirements for a 1985-to-2000 operational aeronautical satellite system.*

1.2 SYNOPSIS OF THE AEROSAT SYSTEM: ITS PURPOSE AND ITS ELEMENTS

As stated in the FAA Program Plan for Aeronautical Satellites (AEROSAT),** "the main problems to be solved by the AEROSAT program are not associated with technological risks nor with the selection of an operational concept which will provide improved performance as compared with today's system. Instead the problem is one of creating a system with sufficient flexibility to permit experimentation and evaluation of competitive technical approaches and viable operational concepts as a means of selecting the best approach, an economically attractive, internationally acceptable operational satellite communication/surveillance system".

The system internationally specified to provide this flexibility consists of a "space-segment capability" and a "coordinated program." The space-segment capability will consist of satellites in orbit and satellite control facilities. The coordinated program will consist of (1) ground facilities comprising Aeronautical Satellite Communications Centers (ASCCs), Aeronautical Services Earth Terminals (ASETs), and interfaces between these elements and Air Traffic Control Centers (ATCCs) and other user communications centers; (2) aircraft avionics; and (3) a coordinated test, evaluation, and demonstration program using the space-segment capability and the other elements of the coordinated program.

In addition to these system elements, two other elements -- Electronic Test Sets (ETSs) and small, remote earth terminals similar to the ETS and called Mini-ASETs -- have been advocated. The ETS has been identified as a method for supporting system performance evaluation and calibration. The Mini-ASET has been identified as part of the U.S. portion of the AEROSAT program in support of the broader system element of "interfaces between ASCCs and ASETs and system ground users", especially in remote geographical areas.

**A Study of the Communications Requirements For A 1985 to 2000 Operational Aeronautical Satellite System*, Danny E. Cornett et al., Report No. FAA-RD-75-80, Volume I - Atlantic Ocean Area, and Volume II - Pacific and Indian Ocean Areas.

***Engineering and Development Program Plan - Aeronautical Satellites (AEROSAT)*, Report No. FAA-ED-17-2, September 1974.

The interconnection of these system elements, extracted from the program plan, is illustrated in Figure 1. The system will include two satellites; two ASETs, one in Europe and one in North America; and three ASCCs. The North American ASET will be shared by the U.S. and Canada, each constructing one-half ASET (capable of accessing one satellite). The two combined will perform the complete function.

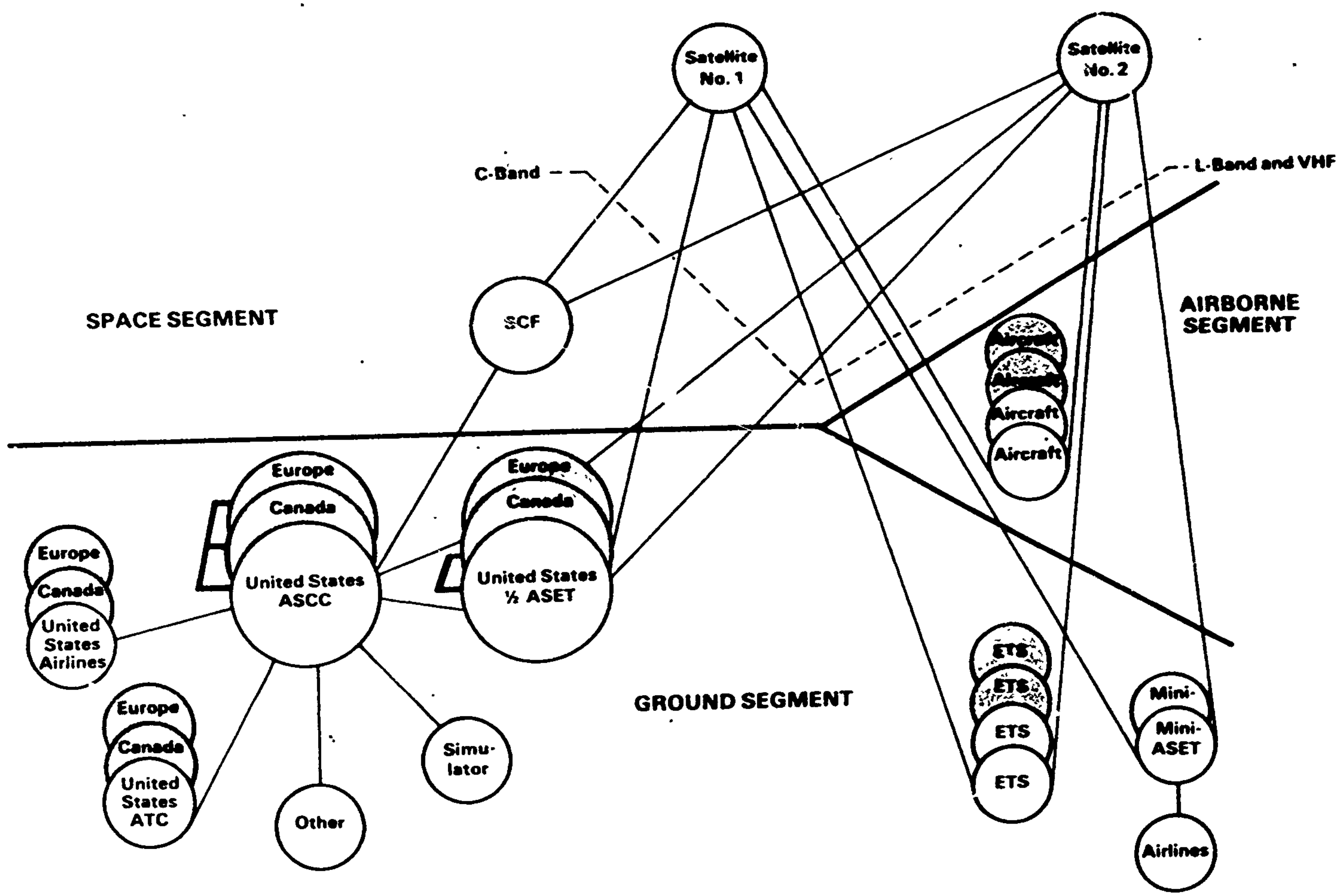
1.3 RELATION OF THE PRESENT STUDY TO OVERALL FAA TEST PLANNING

The FAA, in defining U.S. participation in the coordinated program, has established a four-stage Test and Evaluation Program, the first stage, of which is test planning. Test planning consists basically of the development of a series of test plans culminating in a coordinated Test and Evaluation Plan. As graphically displayed in Figure 2, this section describes the overall elements in the AEROSAT test planning and presents the relationship between the present study and the overall planning effort.

Most of the test requirements will result from the technology and operational test plans. The simulation plan and the data collection, reduction, and analysis plan will define support for technology and operational tests. The prelaunch test plan will detail the testing that will occur during Stage II of the program, which comprises integration testing, simulation tests, and readiness tests prior to the launch of the first satellite. Stage III, the planning for which is contained in the on-orbit test plan, includes readiness tests, one-satellite tests, two-satellite tests, and simulation tests. The wideband experimental test plan, an adjunct of the primary test objectives, will be developed to describe the experimental channel tests to be performed as a research and development program aimed at establishing the technology and testing concepts applicable to possible future CONUS satellite/ATC systems. The system-configuration document will provide the final details of the AEROSAT system design. All of these plans will then be incorporated into a coordinated test and evaluation plan, which will represent the final agreement on all potential testing and evaluation.

The issues selected for examination during this study effort lie within the scope of operational testing, which is distinguished from technology testing by the following definitions:

- Technology Testing consists of those tests whose objectives are to measure or evaluate the capability of equipment to operate according to specified conditions or to compare the capabilities of two or more competing equipments. Technology testing will include propagation measurements, comparative evaluations of hardware and software configurations to determine their effects on overall channel performance, and wideband-ranging performance measurements.



Legend:

ASCC	Aeronautical Satellite Communications Center
½ASET	One-half of an Aeronautical Services Earth Terminal
ATC	Air Traffic Control
ETS	Electronic Test Set
Mini-ASET	Small, Remote Earth Terminal for L-Band and VHF Accessing
SCF	Satellite Control Facility
▭	System for United States Evaluation
▭	System for European or Canadian Evaluation

Figure 1. AEROSAT INTERCONNECTIONS

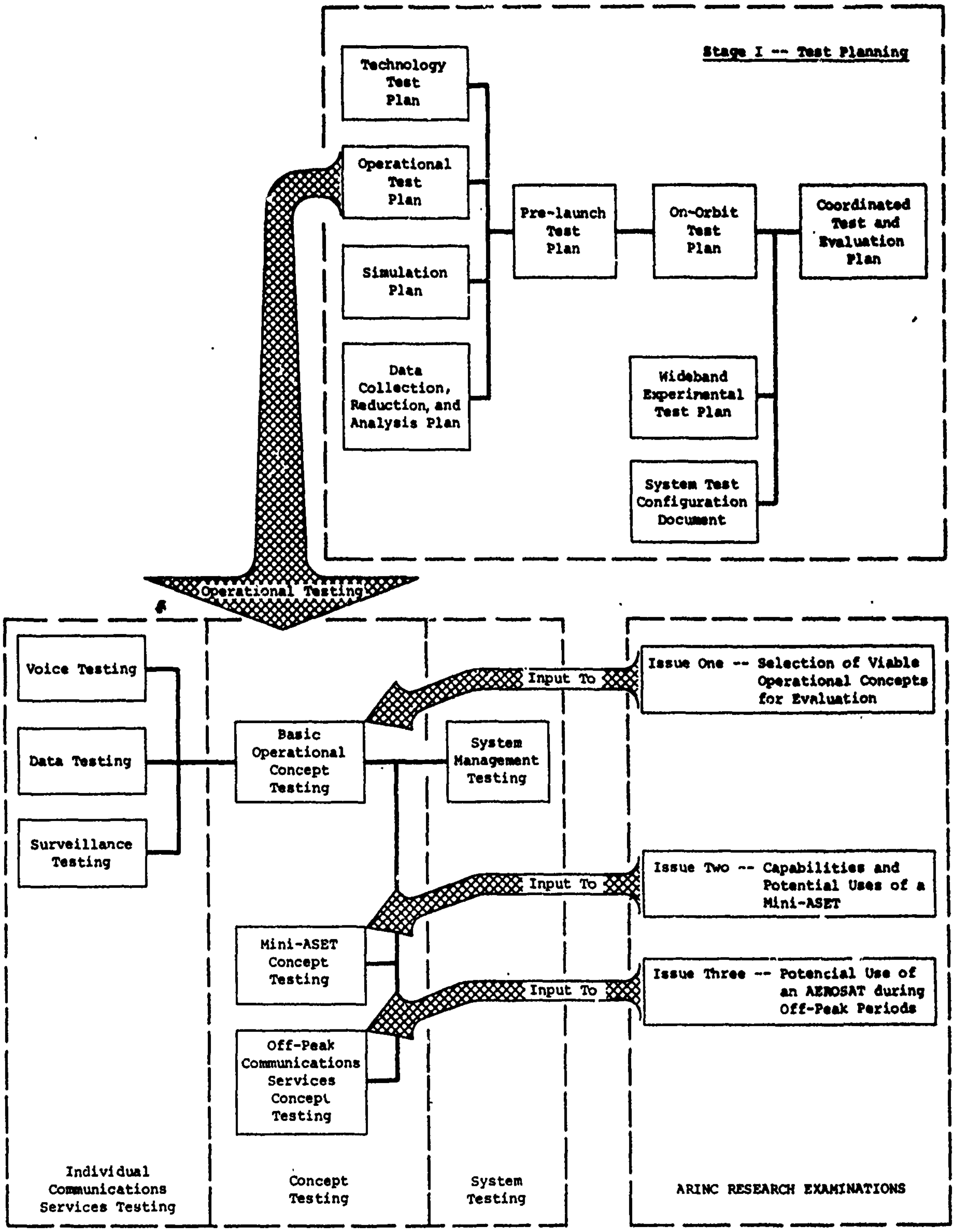


Figure 2. RELATIONSHIP OF PRESENT STUDY TO OVERALL FAA TEST PLANNING

- Operational Testing on the other hand, deals with how the combined capabilities of the equipments are employed to the users' best advantage. The main objectives of operational testing are (1) to arrive at recommendations as to which operational concepts should be implemented in the operational system, (2) to provide a data base for determining the numbers of channels that should be provided by the operational system, and (3) to provide sufficient procedural information on the use of the recommended operational concepts so that Standards and Recommended Practices (SARPS) can be developed.

Operational testing can be viewed as consisting of three levels of testing (see lower left portion of Figure 2). For the first level, individual communications service testing, "ways to conduct" and "ability to utilize received information" tests will be performed for voice, data, and surveillance.

Once individual service testing is complete, testing will be conducted on a user-to-user basis and may employ any service or combination of services. This is called concept testing. Various communications services (e.g., voice only, voice and data, voice and dependent or independent surveillance, etc.), along with selected candidate operation modes (i.e., access control techniques, information-handling techniques, and signaling techniques), will be operated and evaluated to produce data in support of the three main products of operational testing.

Three aspects of concept testing have been identified. The primary aspect, Basic Operational Concept Testing, will deal with fundamental methods used to transfer information between ground users and aircraft via an ASCC and ASET. The two other aspects, both secondary to the basic concepts, postulate expanded forms of information flow. The Mini-ASET concept provides a means for ground users to contact aircraft, and vice versa, other than through direct ground interconnects with an ASCC. The off-peak services concept represents a further expansion of information flow by allowing the transfer of information between ground users during off-peak periods of the day.

System-level testing takes into account the additional information flow between two or more sets of ground facilities that may be necessary to manage the system's resources most effectively. During system-management testing, different allocation techniques and coordination schemes will be evaluated to determine the best way to provide overall system management, including operational issues such as centralized versus decentralized control of channel access, management functions and air traffic control operations, operating procedures and techniques for handing off aircraft from one service area to another, and the ability of a user served by one set of facilities to contact an aircraft served by another set of facilities.

As illustrated in Figure 2, the issues for examination during this study effort were selected to provide inputs to the planning of the three aspects of concept-level testing. A more thorough definition of each of these aspects is presented in subsequent chapters of this report.

1.4 STUDY APPROACH

Upon completion of the study work for an operational Atlantic Ocean aeronautical satellite system*, it was realized that many of the alternatives pointed out in the study report were pertinent to the ongoing test planning for the test and evaluation program. Consequently, the present study was designed to use the information gained during the study of requirements for an *operational* system to provide inputs to the planning of operational evaluations for an *experimentation and evaluation* system.

In parallel with the three issues selected for examination, the work effort was divided into three task areas: basic operational concepts, the Mini-ASET concept, and the off-peak services concept. The approach to each task was basically twofold. First, it was necessary to examine the technical considerations associated with the implementation and operation of each concept. This resulted in a technical description of each concept, including potential communications services, operating modes, and network connectivity. Then present and projected operational conditions (primarily those formulated during the study of communications requirements for an operational system*) were reviewed to determine how each concept might be utilized and to identify conditions that might affect the use of these concepts. For the first task area, basic operational concepts, this review resulted in the identification of a preferred set of basic concepts, prominent implementation considerations, and some recommended test areas. For the two other task areas, potential concept applications and some of the nontechnical factors that might influence any eventual decision to implement these applications were developed.

1.5 ORGANIZATION OF REPORT

The ideas that have resulted from the examination of basic operational concepts, the Mini-ASET concept, and the off-peak services concept are presented in Chapters Two, Three, and Four, respectively. Chapter Five presents conclusions and recommendations.

Appendix A defines some of the terminology used in this report to describe certain methods of operation. Appendixes B and C explain in further detail many of the implementation considerations for two of the

---

*Report No. FAA-RD-75-80, Volume I.

more complex subsystems -- poll-and-response data channels and mark-idle channel scanning -- utilized in several of the preferred basic operational concepts described in Chapter Two. Appendix D provides brief descriptions of several international aviation-related networks that might interface with the AEROSAT system as part of the off-peak services concept discussed in Chapter Four.

CHAPTER TWO

BASIC OPERATIONAL CONCEPTS

2.1 THE ELEMENTS OF A BASIC OPERATIONAL CONCEPT

An operational concept represents the means through which information flows from user to user within the system. It consists of a specified combination of communications services and a particular operating mode and it must accommodate four basic functions: normal communications, emergency communications, surveillance, and supervision. In this chapter, seven alternative concepts are suggested as subjects of more detailed examination as the T&E program evolves. These selected concepts have evolved from a study of communications requirements for a 1985-to-2000 operational satellite system and thus represent initial inputs to the planning of the T&E program.

The communications services that may be offered by the AEROSAT system are voice, data, and surveillance. Surveillance, in a broad functional sense, may be voice position reporting, dependent position determinations, or independent position determinations. However, the voice service would actually be used to conduct voice position reporting and, similarly, the data service to conduct dependent surveillance. Therefore, when reference is being made to a service that is distinct from either voice or data, the term *surveillance service* applies only to independent surveillance. As concepts are described in this chapter, the functional interpretation of surveillance is used to identify precisely which method of position-fixing is being employed.

A concept's mode of operation encompasses the techniques used for access control, information handling, and signaling. Access control consists of the procedures used by ground and mobile users to obtain the use of a particular service and the system's ability to control these accesses and utilize its resources efficiently. The information-handling techniques determine the way in which the various kinds of information are exchanged within the system. Requirements in this area may spell out the need for equipments, such as automatic sensing devices and input/output devices, or particular kinds of transmission capability, such as store-and-forward transmission, multiple-user distribution, use of ground communicators versus automatic exchanges, two-way alternate (half duplex) versus two-way simultaneous (full duplex) operation, and so on. Signaling encompasses the way users are alerted to incoming messages, the methods used to detect message addresses, the identifiers used to route messages through the system, and the signals used to control equipment operations such as modem switching.

The term "basic" is used in this chapter to differeniate the concepts discussed here from the two concepts discussed in subsequent chapters. "Basic" in this context applies to AEROSAT operational concepts that are concerned exclusively with the transfer of information between ground users and aircraft. Figure 3 illustrates this connectivity and the major elements in the user-to-user link. The two concepts discussed in Chapters Three and Four will expand this basic connectivity.

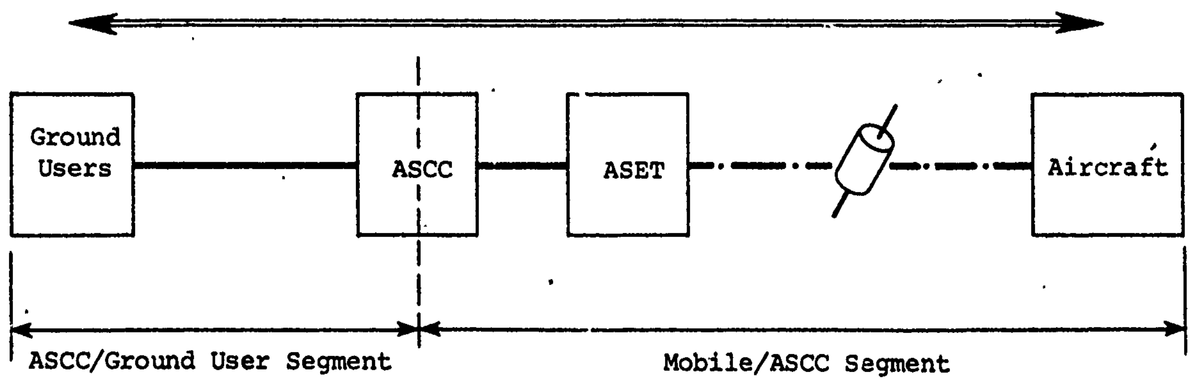


Figure 3. CONNECTIVITY FOR BASIC OPERATIONAL CONCEPTS

Two distinct segments as identified in Figure 3 have a bearing on the concept's ability to fulfill its user-to-user role -- even though the brunt of the AEROSAT concept evaluation will be the consideration of alternatives associated with the mobile/ASCC segment. Consequently, it is important to explain how each segment is to operate and the services that each will provide.

While it is generally agreed that the main goal of concept development is a convenient and efficient way for users to exchange normal, every-day communications, the system engineer must also pay close attention to the way in which the system will handle emergency communications, surveillance, and supervision. For emergency communications, two broad options exist. The system can be provisioned so that rapid, or interrupt, access can be made over normal communication channels to allow near-immediate emergency alerting, or special channels can be allocated for emergency communications only. For surveillance, especially dependent and independent position determinations, consideration of query and response protocols and automatic data processing will become extremely important. The supervision function required to maintain system order and performance quality may be handled through the use of overhead information (e.g., synchronization, address, technical acknowledgement, and error-protection bits) or through the use of signaling information multiplexed with the communication-message waveform.

The complete specification of a basic operational concept should thus spell out the services to be offered bv and the method of operation to be utilized in each of two segments. Equal attention should be given to how the concept will handle normal and emergency communications, surveillance, and supervision. The next question is how many, and which, concepts should be evaluated.

2.2 THE PROBLEM: SPECIFICATION OF A PRACTICAL SET OF CONCEPTS FOR EVALUATION

Table 1 itemizes the primary options or elements that must be considered in developing an operational concept. These elements, associated with the two link segments and pertaining to the services that may be offered and the techniques that may compose the mode of operation, form the building blocks that may be used to construct operational concepts. As explained in the following paragraphs, the concept-specification problem arises from the need to limit the number of concepts selected for evaluation.

Much of the terminology used in Table 1 refers to particular ways of performing system functions or carrying out certain techniques. The reader unfamiliar with portions of this terminology should consult Appendix A for a definition of the various terms.

To construct a concept using these elements, one would select a series of those options which together are operationally sound and are able to accommodate the four basic communications functions. As can be readily seen, exhaustive use of this process will lead to an extremely long list of potential concepts. However, only a small, appropriately chosen set of these is needed to accomplish the goals of the T&E program. Consequently, there is a need to identify and develop a reasonable and well organized, but limited, set of practical operational concepts for long-term evaluation.*

2.3 A PROPOSED SET OF SEVEN CONCEPTS THAT HAVE EVOLVED FROM A STUDY OF COMMUNICATIONS REQUIREMENTS FOR A 1985-TO-2000 OPERATIONAL SYSTEM

During the requirements study for an operational system (Volumes I and II of this report), seven scenarios (see Table 2) were developed to represent the range of communications anticipated for oceanic air travel during the time period 1985 to 2000, including case studies of six communications-load cases. The corresponding message types are shown in Table 3. During the present study, these seven communications scenarios were re-examined to determine the range of operational concepts that should be evaluated to ensure that the AEROSAT system will be able to support all of these scenarios. The preferred communications scenarios and operational concepts will be selected at the end of the T&E program. Coincidentally, seven basic operational concepts were developed to represent this range. While there is not a one-to-one correspondence between the seven operational concepts and the seven scenarios, some correlation does exist, as shown in the last column of Table 2. This correlation indicates which communications-load cases can be associated with each operational concept to provide message characteristics that can be used to simulate or otherwise evaluate the set of operational concepts.

---

*It is recognized that work is being conducted by the Common Systems Working Group to establish, internationally, a comprehensive, yet minimum, set of candidate oceanic systems for common system evaluation. The concepts discussed in this report may be considered a forerunner of the common system operational concepts, and as such, they will hopefully support and supplement, but not duplicate the activities of the common system working group. At some time in the future, it may be desirable to update the configurations presented here on the basis of the efforts completed by the working group.

Table 1. ELEMENTS OF CONCEPT SPECIFICATIONS

Mobile/ASCC Segment	ASCC/Ground User Segment

Communications Services
    Voice
    Data
    Surveillance
	Communications Services
	    Voice
	    Teletype
	    Medium-Speed Data

Access Control Techniques
    Ground-Air
        Semipermanent channel assignment
        Channel scanning
        Supervisory channel assignment
    Air-Ground
        Seizure at random
        Seizure after listening
        Seizure after observing channel status indicator
        Calling at random
        Calling by response to periodic poll
	Access Control Techniques
	    Dedicated User Circuits
	    Net Operation

Information-Handling Techniques
    One-Way Air-To-Ground Exchange
    Two-Way Paired Channel
        Conversational exchange
        Poll-and-response exchange
    Two-Way Independent Exchange
	Information-Handling Techniques
	    Direct Interconnection (Channel Switching)
	    Store and Forward (Message Switching)

Signaling Techniques
    Over Working Channel
        Identification by voice
        Dial pulse or inband signals
        Use of overhead bits
    Over Supervisory Channel
        Identification by voice
        Dial pulse or inband signals
        Use of overhead bits
    For Selecting and Switching Equipment
        Use of overhead bits for modems in ASET
        Use of overhead bits for aircraft modems and peripherals
	Signaling Techniques
	    Over the Working Channel
	        Identification by voice
	        Dial pulse or inband signals
	        Use of overhead bits
	    Over a Supervisory Channel
	        Identification by voice
	        Dial pulse or inband signals
	        Use of overhead bits

Table 2. CHARACTERISTICS OF SATELLITE SYSTEM SCENARIOS

Scenario	Communications Load Case	Operating Discipline	Queueing Model	Concept/Scenario Correlation
A	Case I - all voice communications consisting of present message types.	Undisciplined voice	Single servers in parallel.	Concepts 1 and 2 would use this scenario. Concept 3 would use the scenario A load case, but it would exemplify a disciplined-voice operating discipline and a no-queue situation.
B	Case II, Option A - voice communications except for position-fixing and specific weather information. Minimum data-link capability. No aircraft display capability. Present message types. Dependent surveillance.	Undisciplined voice and minimum-capability poll and response data link.	Single servers in parallel for voice; no queueing model for data link.	Concept 4 would be characterized by this scenario.
C	Case II, Option B - minor expansion of Scenario B data-link capability. Voice communications for most messages. Data link for position-fixing, specific weather, and short, time-critical ATC messages. Aircraft has display capability. Dependent surveillance.	Disciplined voice and poll and response data link.	Multiserver queue for voice; no queueing model for data link.	Concept 5 would be characterized by this scenario.
D	Case III - expanded use of data for ATC communications. Company communications primarily voice. Full aircraft data-link display capability. Dependent surveillance.	Disciplined voice and poll and response data link.	Multiserver queue for voice; no queueing model for data link.	
E	Case IV - identical to Case III, except that position-fixing information is no longer transmitted on the data link. Independent surveillance.	Supervisory channel utilized for control management and transmission of surveillance ranging signals. Supervisory channel operated as a poll and response data channel. Disciplined voice and demand-assigned data channels are utilized.	Multiserver queues for voice and demand-assigned voice; no queueing model for supervisory channel.	These scenarios illustrate the range of load cases that may be evaluated in Concept 6 and, for the most part, in Concept 7. But, while Concept 6 operates almost exactly as specified in these scenarios, Concept 7 utilizes a channel-scanning operating discipline and a no-queue protocol to achieve the same demand-assigned effect.
F	Case V - full expansion of ATC and company communications. Heavy use of data communication. Voice communications utilized for selected messages. Full aircraft data-link display capability. Dependent surveillance.	Disciplined voice, poll, and response data for dependent surveillance and specific weather requirements; and demand-assigned data for remaining data messages.	Multiserver queues for voice and demand-assigned data; no queueing model for poll and response data.	
G	Case VI - identical to Case V, except that position-fixing information is no longer transmitted on the data link. Independent surveillance.	Supervisory channel utilized for control management and transmission of surveillance ranging. signals. Supervisory channel operated as a poll and response data channel. Disciplined voice and demand-assigned data channels are utilized.	Multiserver queues for voice and demand-assigned voice; no queueing model for supervisory channel.	

Table 3. MESSAGE TYPES ASSOCIATED WITH EACH COMMUNICATIONS CASE

Message Type	Message Type Used at Present	Transmission Mode by Communications Case											
		Case I		Case II		Case III		Case IV		Case V		Case VI	
		Voice	Data	Voice	Data	Voice	Data	Voice	Data	Voice	Data	Voice	Data
ATC and Related Communications													
ATC Instructions													
Route Control	X	X		X			X		X		X		X
Altitude Control	X	X		X^1	X^2		X		X		X		X
Clearance Control	X	X		X			X		X		X		X
Flight-Plan Revision	X	X		X		X		X			X		X
Speed Control	X	X		X^1	X^2		X		X		X		X
ATC Support Messages													
Position Fixing (Position and Altitude)	X	X			X		X				X		
Route/Speed	X	X		X		X		X			X		X
ATC Advisories													
Essential Traffic Information	X	X		X			X		X		X		X
Aircraft-Status Information	X	X		X		X		X			X		X
Airport-Status Information	X	X		X			X		X		X		X
Altimeter-Setting Information	X	X		X^1	X^2		X		X		X		X
Meteorological Information													
General Weather	X	X		X			X		X		X		X
Specific Weather	X	X			X		X		X		X		X
Company-Related Communications													
Flight Operations													
Departure/Arrival Report	X	X		X			X		X		X		X
Flight Progress/Deviation Report	X	X		X		X	X	X	X	X	X	X	X
Flight Conditions	X	X		X		X		X		X		X	
Gate Assignments										X	X	X	X
Crew Physiological and Performance Monitor											X		X
Manifest Check (Weight and Balance)	X	X		X		X		X			X		X
In-Flight Maintenance Support													
Airplane Condition Reports	X	X		X		X		X		X		X	
Aircraft/Engine Parameters (Automatic Readout)											X		X
Engineering Assistance						X		X		X		X	
Flight Management/Logistics													
Cabin Services	X	X		X		X		X			X		X
Seat Occupancy, Passenger Manifest, Flight Connections											X		X
Immigration, Public Health, Passport											X		X
In-Flight Passenger Services													
Request for Ground Assistance (Wheelchairs, etc.)	X	X		X		X		X			X		X
Rental Car, Hotel, and Ground Service Reservations										X	X	X	X
Individual Passenger Airline Reservations										X	X	X	X
Medical Advisory/Consultation	X	X		X		X		X		X		X	
Interpreter Service											X		X
Business and Personal Messages											X		X
Aircraft-On-Ground Services						X		X		X		X	
Communications Management													
Radio Equipment Checks	X	X		X			X		X		X		X
SELCAL Check	X	X		X									
Transfer of Control/Frequency Change	X	X		X^1	X^2		X		X		X		X

[1] Used in Option A of Case II.

[2] Used in Option B of Case II.

The major specification elements of each concept are summarized in the checklist of Table 4. Section 2.3.1 expands the description of each concept. Then Sections 2.3.2 and 2.3.3 present, respectively, technical and operational factors and some suggested test areas associated with the seven concepts.

2.3.1 Concept Descriptions

The seven concepts can be classified into three broad groups according to the communications services that they provide. Concepts 1, 2, and 3 provide voice communications with voice position reporting, and they differ primarily in the way access control is conducted. Voice communications with dependent and/or independent surveillance are provided by Concepts 4 and 5. In Concept 4 voice channels are operated independently of the surveillance subsystem, and voice-channel access is obtained by means of a seizure method. In Concept 5, on the other hand, voice channels are requested on a demand basis from a common-channel pool through the use of a data-link supervisory/surveillance channel. Concepts 6 and 7 provide for both voice and data communications. Concept 6 offers dependent and/or independent surveillance, while Concept 7 is limited to independent surveillance. Concept 6 utilizes a supervisory channel-assignment protocol, whereas Concept 7 employs a channel-scanning technique. The prominent features of each concept are highlighted in Figures 4 through 10. Brief narrative descriptions of the concepts are given in the following paragraphs.

2.3.1.1 Concept 1: An All-Voice System Using Seizure After Listening (see Figure 4)

The Concept 1 system would operate in much the same way as today's high frequency (HF) radiotelephone network. Voice channels are managed at the ASCC by ground communicators and are assigned to aircraft on a semi-permanent basis. Each pilot continuously monitors a single forward (ground-to-satellite-to-aircraft) channel and initiates communication on an associated return (aircraft-to-satellite-to-ground) channel when he believes that the channel is idle. This determination is made solely by listening for conversation on the forward channel. When there is no conversation (say for three seconds), the pilot assumes that the associated return channel is idle and begins conversation. In reality, the return channel may not be idle (i.e., another pilot is talking) and interference (i.e., garble) would result. This potential for interference may be the greatest disadvantage of this concept. Measures such as rebroadcast of air-to-satellite-to-ground transmissions over an associated forward channel and the techniques used in subsequent concepts may be introduced in an attempt to minimize the interference potential. This issue is discussed further in Section 2.3.2.1.

Voice and teletype circuits are provided between the ASCC communicators and ground users (e.g., airline communicators and air traffic controllers). The ASCC communicator can process communications in one of three ways: (1) set-up a direct two-way voice connection between a ground user and an

Table 4. SUMMARY OF CONCEPT CHARACTERISTICS

Specification Element	Concept 1	2	3	4	5	6	7
Mobile-To-ASCC Segment							
Communications Services							
Voice Communications	X	X	X	X	X	X	X
Data Communications						X	X
Surveillance							
Voice Position Reporting	X	X	X				
Dependent Position Determination				X[5]	X[5]	X[5]	
Independent Position Determination				X[5]	X[5]	X[5]	X
Access Control Techniques							
Ground-Air							
Semipermanent channel assignment	X	X		X			X[12]
Channel scanning			X				X[12]
Supervisory channel assignment					X	X	
Air-Ground							
Seizure at random	X[1]	X[1]	X[1]	X[1]			X[1]
Seizure after listening	X			X[13]			
Seizure after observing channel status indicator		X	X[4]	X[13]			X[4]
Calling at random							
Calling by response to periodic poll					X	X	
Information-Handling Techniques							
One-Way Air-To-Ground Exchange	X[1]	X[1]	X[1]	X[1]			X[1]
Two-Way Paired Channel							
Conversational exchange	X	X	X	X[6]	X[8]	X[9]	X[12]
Poll-and-response exchange				X[6]	X[8]	X[10]	X[12]
Two-Way Independent Channel Exchange							
Signaling Techniques							
Over the Working Channel							
Identification by voice	X	X		X[6]			
Dial-pulse or inband signals			X				X[12]
Use of overhead bits				X[6]			X[12]
Over a Supervisory Channel							
Identification by voice							
Dial-pulse or inband signals							
Use of overhead bits					X[8]	X[10]	
For Selecting and Switching Equipments							
Use of overhead bits for modems in ASET						X	X
Use of overhead bits for aircraft modems and peripherals						X	X
ASCC-To-Ground-User Segment							
Communications Service							
Voice	X[2]	X[2]	X	X[7]	X[14]	X[11]	X[11]
Teletype	X[3]	X[3]		X[7]		X[11]	X[11]
Medium-Speed Data				X[7]	X[14]	X[11]	X[11]
Access Control Techniques							
Dedicated User Circuits	X[2]	X[2]	X	X	X	X	X
Net Operation	X[3]	X[3]					
Information-Handling Techniques							
Direct Interconnection (Channel Switching)	X[2]	X[2]	X	X[7]	X[14]	X[11]	X[11]
Store and Forward (Message Switching)	X[3]	X[3]		X[7]	X[14]	X[11]	X[11]
Signaling Techniques							
Over the Working Channel							
Identification by voice							
Dial-pulse or inband signals	X[2]	X[2]	X	X[7]		X[11]	X[11]
Use of overhead bits	X[3]	X[3]		X[7]		X[11]	X[11]
Over a Supervisory Channel							
Identification by voice							
Dial-pulse or inband signals							
Use of overhead bits					X[14]		

Notes

[1] Used for experimentation of dedicated one-way channels for emergency alerting.

[2] Voice service uses dedicated user circuits, channel switching, and inband signaling.

[3] Teletype uses net operation, message switching, and overhead characters for identification.

[4] Employs automatic, rather than manual, seizure techniques based on channel status indicators.

[5] Dependent or independent surveillance, or both, can be achieved by using these concepts.

[6] Conversational exchange used for voice with voice identification; poll-and-response exchange for surveillance transfers using overhead bit identification.

[7] Voice is distributed on ground by communicators using voice and teletype circuits and performing channel or message switching. Surveillance data results are sent to users on medium-speed data circuits using overhead bits for identification.

[8] Conversational exchange used for voice, and poll-and-response exchange used for surveillance transfers and voice-channel request/assignment information.

[9] Conversational exchange used for voice and long data messages.

[10] Poll-and-response exchange used for surveillance transfers, short data-message transfers, and voice or data-channel request/assignment information.

[11] Voice and long data messages are distributed, respectively, on voice and teletype circuits using channel switching and inband signaling. Surveillance data results and short data messages are distributed over medium-speed data circuits using message switching and overhead bit identification.

[12] Semipermanent channel assignment operating in poll-and-response mode and using overhead bit identification is employed solely to transfer independent surveillance signals. Channel-scanning subsystem transfers all voice and data communication and uses inband signaling.

[13] Either of these methods may be used.

[14] Supervision is conducted between ASCC and ground users by using overhead bits via a medium-speed data circuit. Voice connections are made by channel switching on the basis of supervisory information received on the data circuit. Also, data circuit used to transfer data information (e.g., surveillance results).

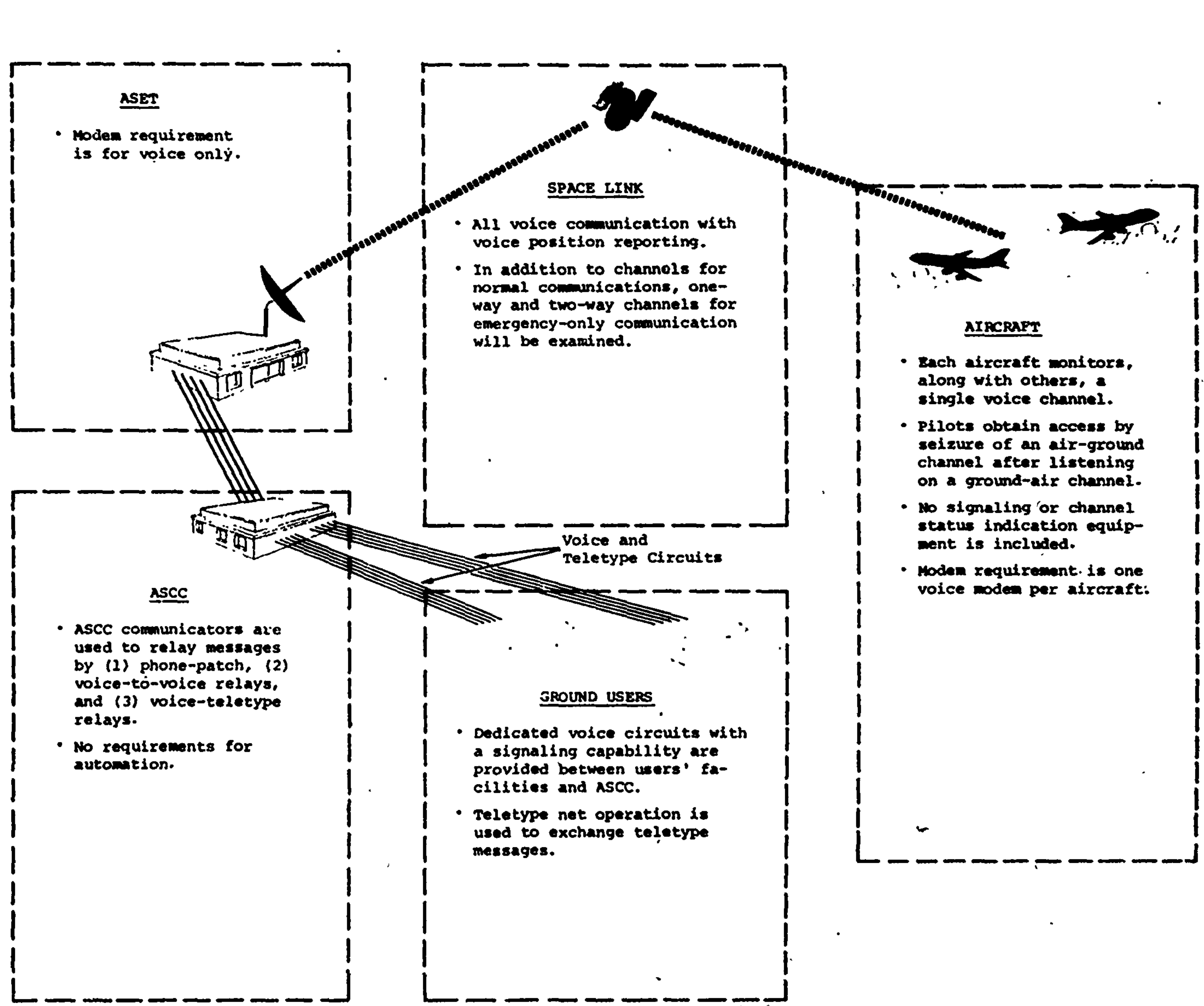


Figure 4. HIGHLIGHTS OF CONCEPT 1: AN ALL-VOICE SYSTEM USING SEIZURE AFTER LISTENING

aircraft; (2) receive a voice communication and then relay the information obtained to the intended user(s) by voice; or (3) distribute voice communications from aircraft by transferring the information onto a teletype circuit with appropriate routing information, and to aircraft by reversing this sequence of events.

In addition to the normal elements of operation, one-way return channels that are manually tuned and seized at random are provided so that several emergency communications protocols (see Section 2.3.2.4 for a discussion of these) can be investigated.

2.3.1.2 Concept 2: All Voice System Using Channel-Status-Indication Seizures (see Figure 5)

Concept 2 differs from Concept 1 in that pilots (and ground communicators, if desired) have a positive indication of channel status. Pilots still monitor a single forward channel but initiate communications on an associated return channel on the basis of the channel status provided from the ASCC over the forward channel. A channel-busy or channel-idle signal may be used in conjunction with a tone or lamp indicator installed in the cockpit. The channel-status signal may be inband and transmitted during idle times or out-of-band and multiplexed with the forward communication signal. A channel-idle indication philosophy implies a continuously transmitted signal on the forward channel, which in turn implies that, as a minimum, the ground equipment would operate in a full duplex fashion.

The ground circuit arrangements, the ground communicator operations, and the provision of one-way return channels for emergencies are the same as in Concept 1.

2.3.1.3 Concept 3: Automated Voice System Using Mark-Idle Channel Scanning (see Figure 6)

As opposed to the channel-assignment method of the first two concepts, the voice channels of Concept 3 are assigned on a demand basis by using a channel-scanning avionics receiver, and seizure of a return channel is performed automatically by the avionics upon request from the pilot. The mark-idle channel-scanning protocol basically calls for a dynamic channel-idle identification process under automatic control in the ASCC. The avionics must be able to select the channel marked idle from among the channels in a pool by scanning, lock onto the mark-idle channel, and automatically seize the available channel when required.

At any given instant, all idle aircraft (i.e., idle from a communications sense) are locked onto a single channel. As soon as the avionics in one of these aircraft seizes this channel (say channel 1), then the ASCC transfers the mark-idle signal to another channel (say channel 2). All the avionics, except the one that initiated communication, then scan and lock onto the second channel (channel 2). This process continues until all of the channels in the pool are busy (a rare situation), at which time no mark-idle signal is transmitted from the ASCC and thus any additional communications are

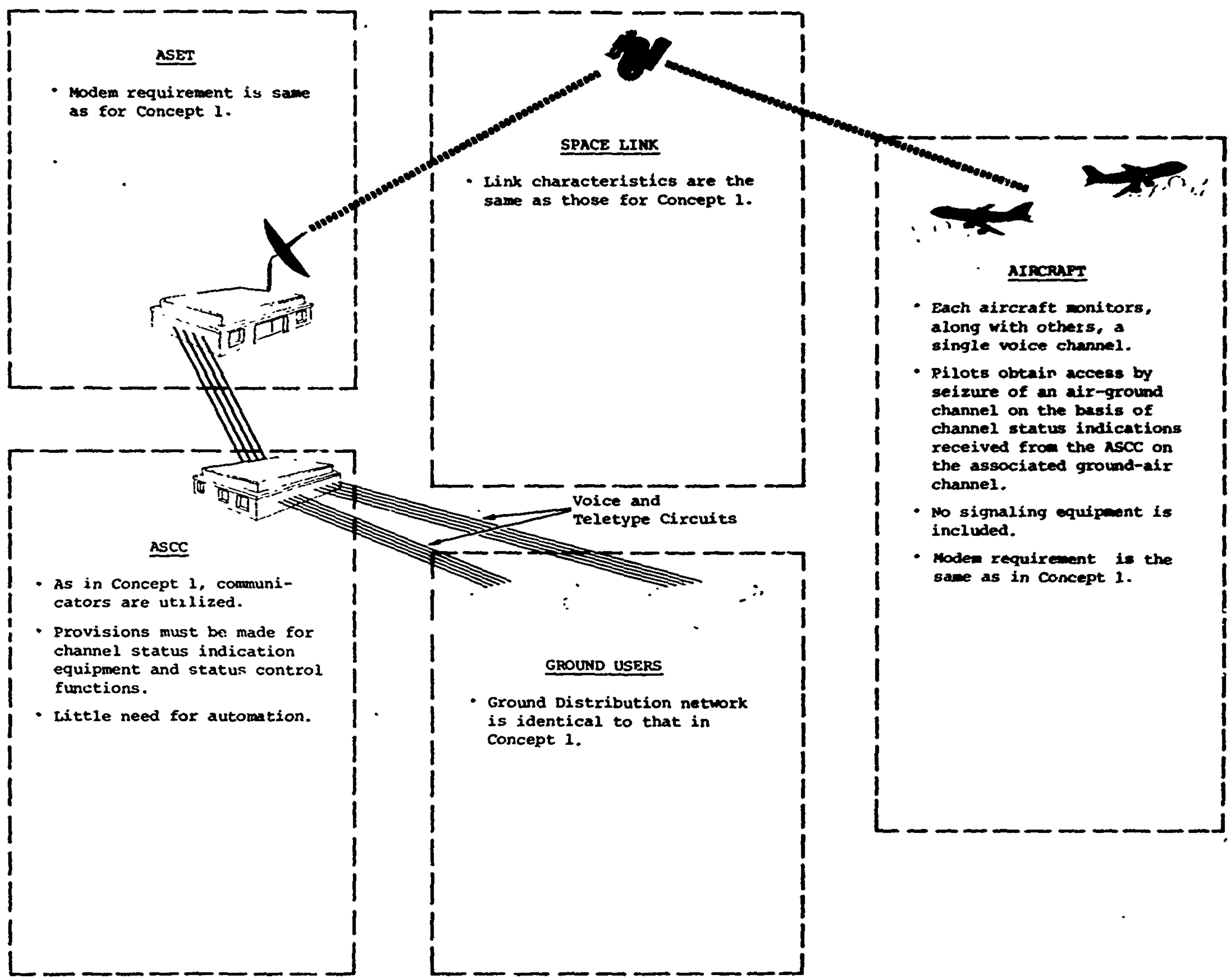


Figure 5. CONCEPT 2 HIGHLIGHTS: ALL VOICE SYSTEM USING CHANNEL-STATUS-INDICATION SEIZURES

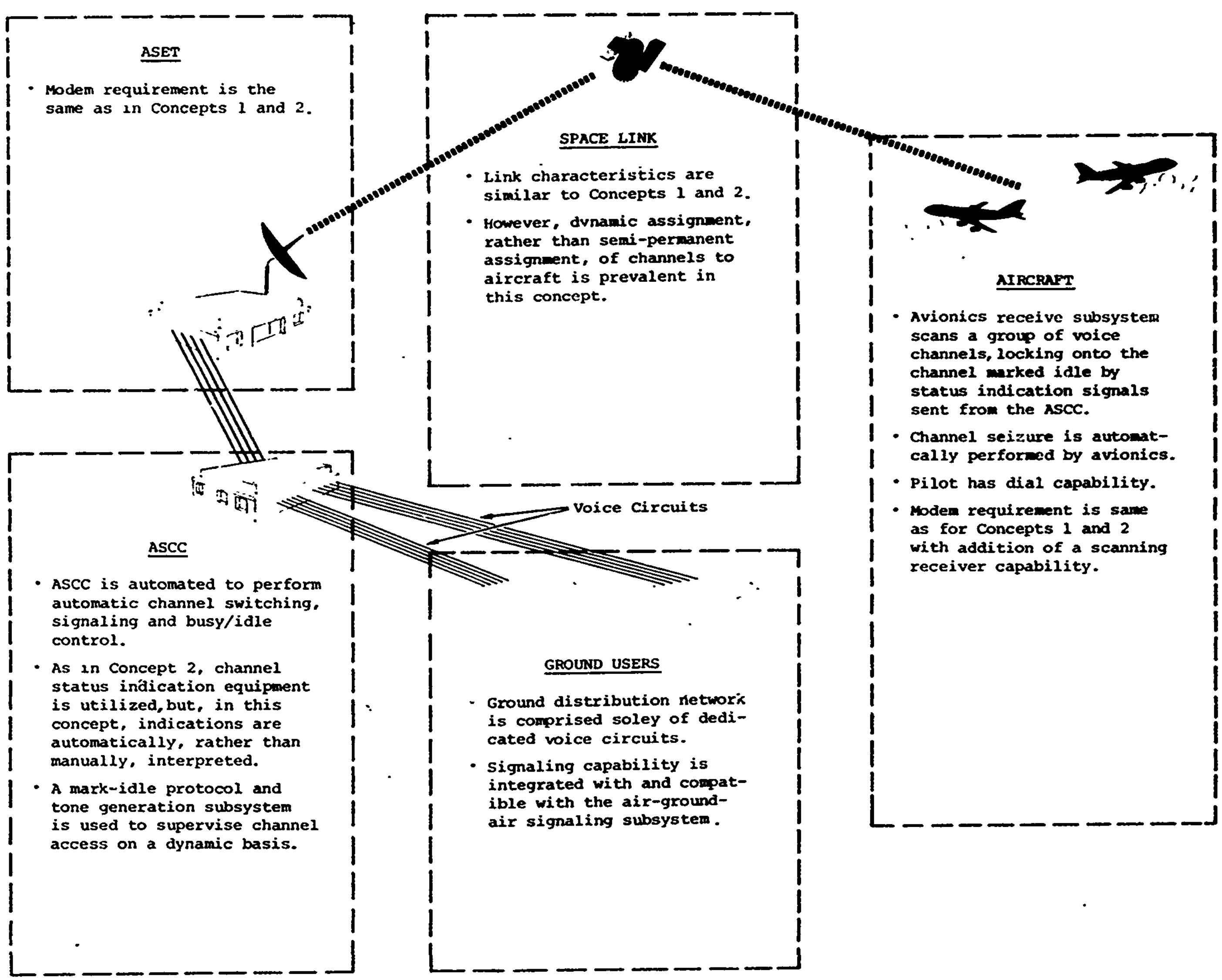


Figure 6. CONCEPT 3 HIGHLIGHTS: AUTOMATED VOICE SYSTEM USING MARK-IDLE CHANNEL SCANNING

blocked. As soon as one channel becomes available, the mark-idle signal is transmitted on that channel, idle aircraft lock on, and the normal process continues.

The advantage of a method of operation such as this over those of the first two concepts is that pilots are given the first available channel for communication from among the total number of channels in the pool rather than being assigned one of the channels for long-term monitoring. The primary effect is the difference between single-server and multi-server queues (see Section 5.2.3 of Volume I for an explanation).

The ASCC is automated to sequence the mark-idle signal (basically a channel-status indicator as in Concept 2) and to perform channel switching between the mobile/ASCC-segment voice channels and the channels between the ASCC and ground users. No ASCC communicators are utilized, and ground distribution consists solely of dedicated voice circuits. An end-to-end signaling subsystem is employed to provide all users (ground and mobile) with a dial capability.

To facilitate rapid access for emergency communications, this concept includes one-way return channels, as in Concepts 1 and 2, and manual capabilities (1) to override the automatic channel-scanning protocol; (2) to tune to an emergency channel; and (3) through some automated protocol, to return to normal operation.

2.3.1.4 Concept 4: A Primarily Voice Communications System Using Seizure Techniques but Providing Automatic Surveillance (see Figure 7)

A voice-channel subsystem and a data-link subsystem, each operated and managed for the most part independently, comprise the communications services offered by Concept 4. Aircraft are required to monitor simultaneously one voice channel and one data channel. The data-link subsystem is operated as a poll-and-response communications network and is used to provide dependent or independent surveillance, and possibly to transfer other, "for the record" information that can be automatically generated in the aircraft and automatically processed on the ground. These data-information exchanges could include position-fixing information (i.e., coordinates and altitude), ranging signals (used for independent position determinations), aircraft speed, specific weather (static air temperature and wind velocity and direction), fuel on board, departure and arrival reports, and airframe and engine status parameters. The voice channels would handle the remainder of the communications. The pilot would have no access to the data-channel subsystem.

The voice channels are accessed and managed through the use of channel-status indicators, as in Concept 2, or seizure after listening, as in Concept 1. Access to the data link is controlled by the polling protocol established and administered by the ASCC. In general, each aircraft is polled at a prescribed rate over a forward data channel and is given the opportunity to respond to the poll over a return data channel.

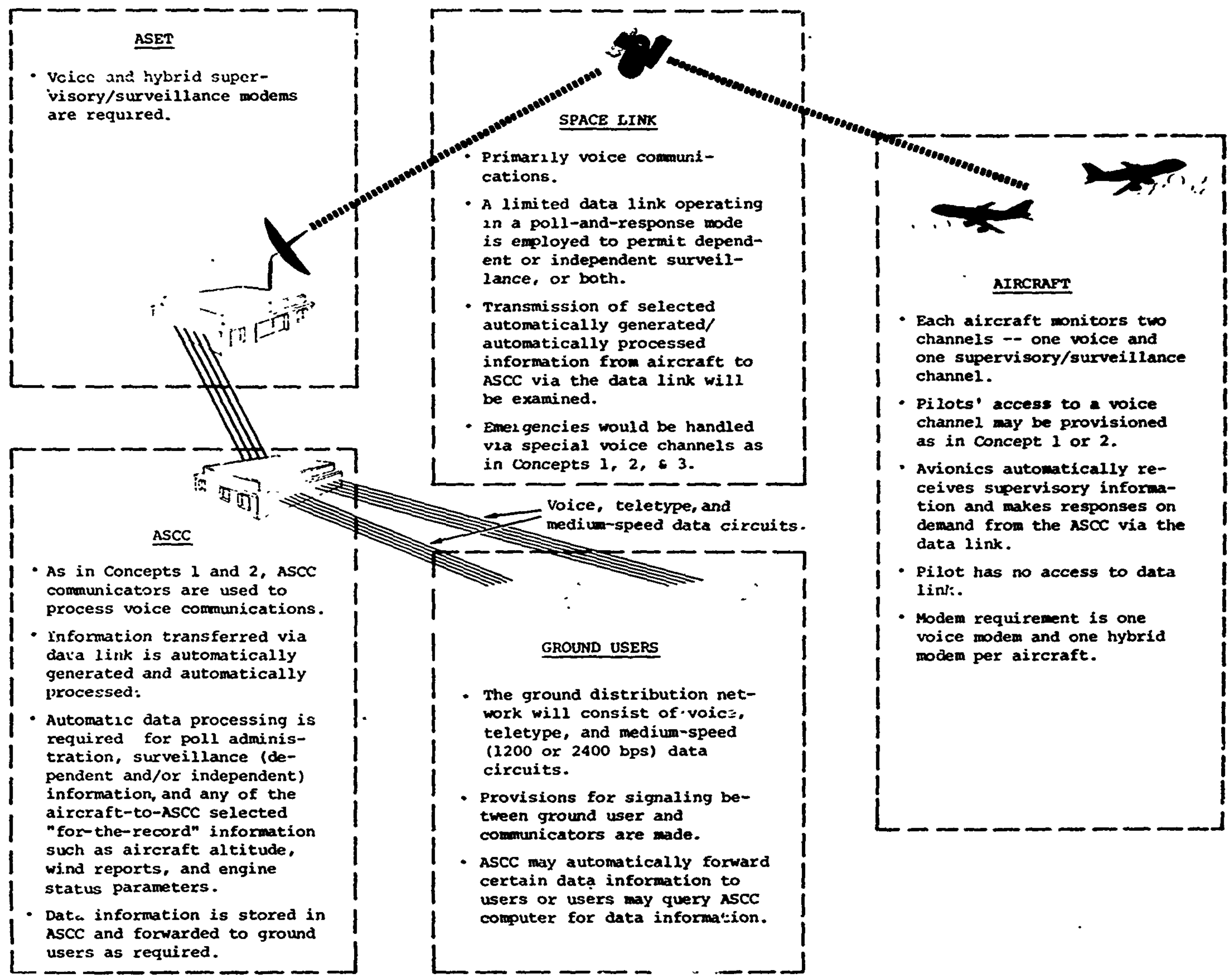


Figure 7. CONCEPT 4 HIGHLIGHTS: A PRIMARILY VOICE COMMUNICATIONS SYSTEM USING SEIZURE TECHNIQUES BUT PROVIDING AUTOMATIC SURVEILLANCE

Voice, teletype, and high-speed data circuits are provided between the ASCC and ground users. ASCC communicators are used to manage the air-ground-air voice channels. Voice communications are processed in the three ways defined in Concept 1: direct voice, relayed voice, and voice-teletype transfer. Information exchange over the data link is automatically processed in the ASCC by means of store-and-forward techniques. The high-speed data circuits are used to route data information to and from ground users.

Emergency communication provisions are the same as in Concepts 1 and 2.

2.3.1.5 Concept 5: An Integrated Voice Communications and Automatic Surveillance System (see Figure 8)

The basic differences between Concept 5 and Concept 4 are as follows: Aircraft monitor only the poll-and-response data channel; voice channels are assigned on a demand basis by a request via the data channel; and the ASCC automatically processes voice communications using channel switching, and data transmissions using message switching.

In addition to the provisions in Concept 4 for dependent and independent surveillance and "for the record" data exchange, it is advantageous in this concept to provide the necessary input/output devices to transfer short, manually generated messages ground-to-air and air-to-ground. The additional data exchanges could include time-critical air traffic control messages (e.g., route, altitude-clearance, and speed-control instructions, and essential traffic information), airport status information (e.g., runway in use and condition of landing aids), estimated times of arrival, altimeter-setting information, and voice-frequency-assignment information. Voice communications would be used for long ATC messages (e.g., flight-plan information, aircraft status, and route and speed listings by segment); general weather; and company operational control messages, including flight conditions, maintenance, cabin services, request for ground assistance (wheelchair, forklift, etc.), and medical consultation.

The voice channels are accessed in the aircraft (1) by pushing a "request voice channel" button on the cockpit display unit, causing the avionics to transmit a special label on the next poll response to indicate the request, or (2) by a ground user's sending a request to the ASCC over a data circuit. The data-link subsystem is operated in the same way as in Concept 4, with the added provisions for manual data inputs.

Requests for voice channels are automatically processed in the ASCC. This requires that ground and mobile users be able to send address information along with their request label. The ASCC automatic exchange detects an address, performs the appropriate channel switching, and then transmits signaling information to the called party. When the called party is aboard an aircraft, the ASCC processing equipment automatically polls the aircraft and transmits channel-assignment and channel-frequency information. The pilot is alerted, and conversation begins. For pilot-initiated calls, the ASCC uses data protocol via a medium-speed data circuit to notify the appropriate ground user. When all voice channels are busy,

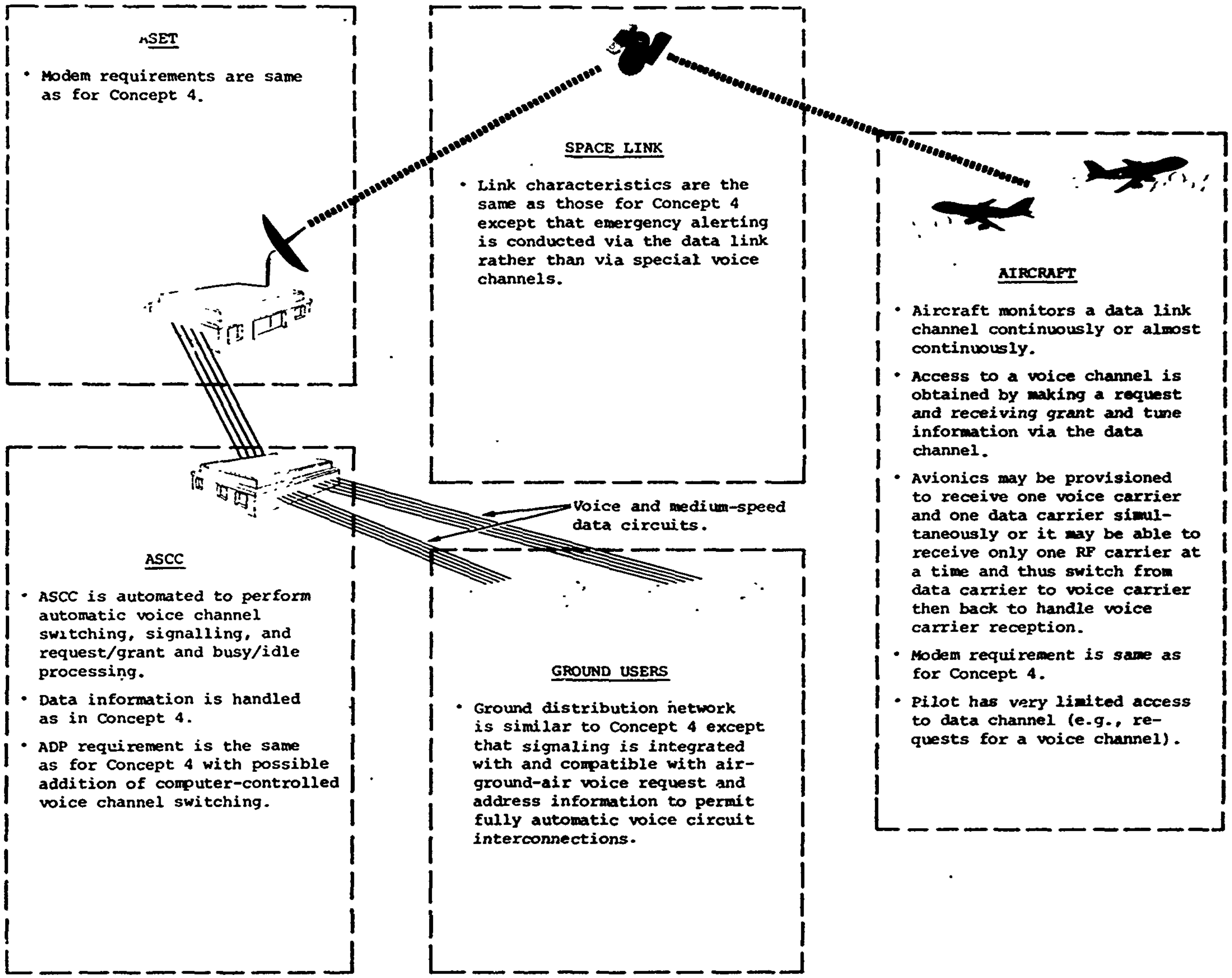


Figure 8. CONCEPT 5 HIGHLIGHTS: AN INTEGRATED VOICE COMMUNICATIONS AND AUTOMATIC SURVEILLANCE SYSTEM

the ASCC responds to any requests by sending a "busy channel" label to the caller and placing the request in queue until a channel becomes available.

For data information exchange, messages are routed to the appropriate user on a store-and-forward basis as in Concept 4. Whereas in concepts 1 through 4 one-way return voice channels are allocated for emergency-only communications, in Concept 5 emergency alerts are conducted over the data-link channel (see Appendix B for an explanation of these provisions).

2.3.1.6 Concept 6: Supervisory Data-Link System Protocol Providing Voice and Data Communications and Automatic Surveillance (see Figure 9)

A demand-assigned voice-channel subsystem, a demand-assigned data-channel subsystem, and a supervisory surveillance subsystem operating in a poll-and-response data mode comprise the communications services offered by this concept. Each aircraft is assigned to and continuously monitors a supervisory poll-and-response data channel. This channel conducts dependent and/or independent surveillance; short air-to-ground and ground-to-air data exchanges; and system supervision, including the request and assignment of voice and data channels on a demand basis. Long voice and data messages are handled by the remainder of the channels.

The voice channels and the demand-assigned data channels are accessed by request. A mobile user makes a request via the supervisory subsystem by pushing a "request voice" or "request data" button on the cockpit input/output device. A ground user makes a request to the ASCC on a medium-speed data circuit. From among the channels available for demand assignment, one group of channels can be marked for voice and the other group marked for data on a semi-permanent basis, or every channel can be marked for data or voice each time there is a demand for its use. The latter approach provides more flexibility in the use of each demand-assigned channel, which may have a significant effect on the maximum utilization that can be achieved on each channel. On the other hand, this approach requires modem switching at the ASET in addition to the normal channel switching within the ASCC. Control functions are therefore more complex.

The supervisory/surveillance subsystem operates in the same general manner as the poll-and-response data-link subsystem used in Concepts 4 and 5 -- each aircraft is polled at a prescribed rate over a forward supervisory channel and is given the opportunity to respond to the poll over a return supervisory channel.

Voice-grade and data-conditioned circuits are used to distribute the information received from or destined for the demand-assigned satellite channels. The ASCC processes these information exchanges automatically through the use of channel switching and signaling techniques. When a request for a voice or data channel is received from an aircraft via the supervisory subsystem, the ASCC processing equipment (1) selects an

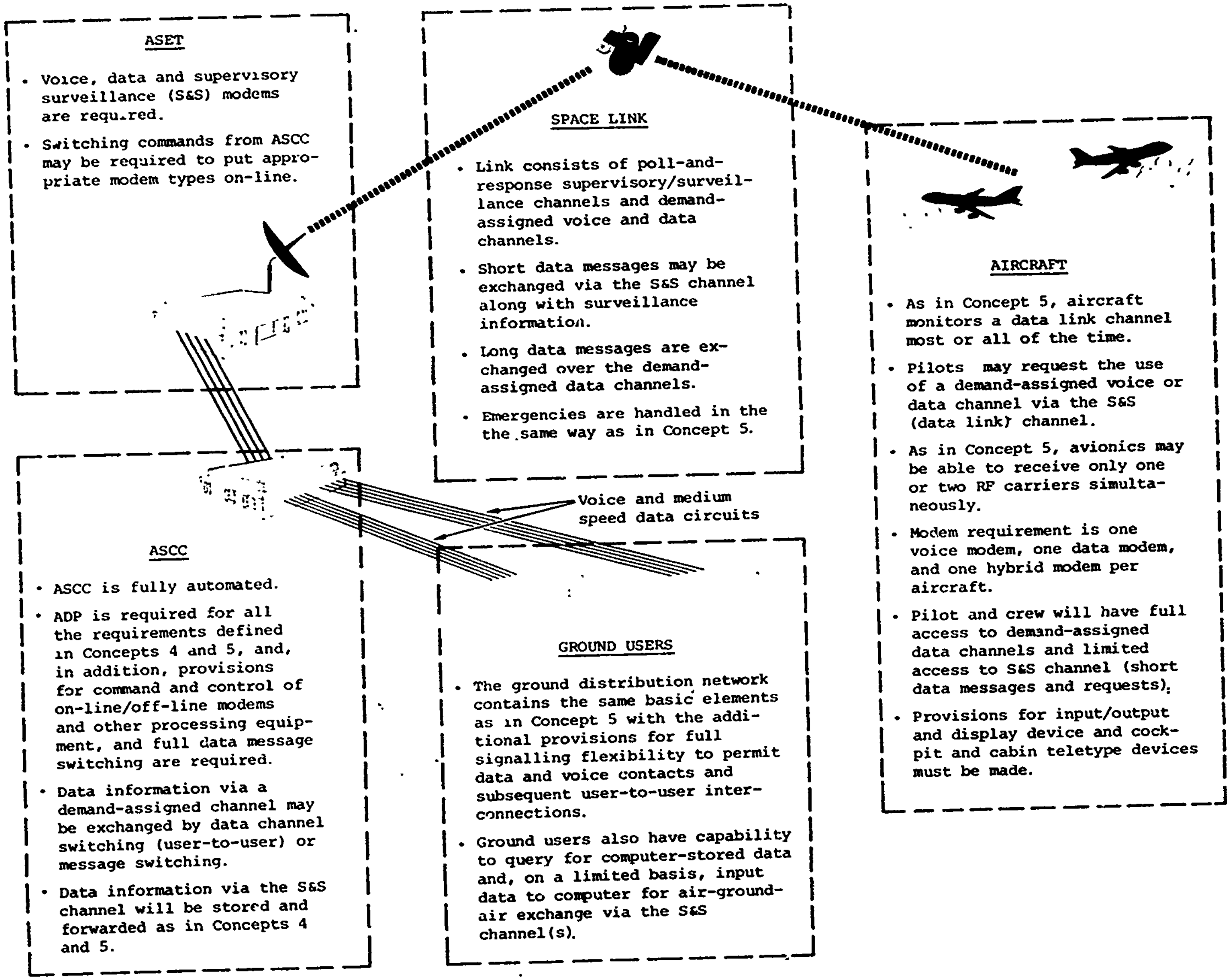


Figure 9. CONCEPT 6 HIGHLIGHTS: SUPERVISORY DATA-LINK SYSTEM PROTOCOL PROVIDING VOICE AND DATA COMMUNICATIONS AND AUTOMATIC SURVEILLANCE

available channel; (2) returns channel and frequency-assignment information to the aircraft and, in the case of the demand-mark approach, voice or data-modem switching information to the ASET and the aircraft; (3) signals the called ground user via the data-circuit subsystem; and (4) performs the necessary interconnection so that communication can begin. When the ASCC receives a request from a ground user via the data-circuit subsystem, the processing equipment detects the address of the party called, selects an available voice or data channel, transmits channel-assignment and frequency-assignment information to the aircraft over the supervisory system, and performs the necessary interconnection so that communication can begin.

Information exchanged via the supervisory/surveillance subsystem is transferred between the ASCC and ground users on a store-and-forward basis.

As in Concept 5, provisions for rapid-access emergency alerts via the supervisory/surveillance subsystem are included in Concept 6.

2.3.1.7 Concept 7: Voice and Data Communications Via a Mark-Idle Channel Scanning System and Provisions for Independent Surveillance (see Figure 10)

All voice and data communications are conducted in Concept 7 through the use of a mark-idle channel-scanning system very much like the one defined for Concept 3. Independently of this system, a low-speed (for example 300 bits/second) surveillance gating and transponding channel is employed to provide an independent surveillance capability.

The mark-idle channel-scanning system, working as described in Concept 3, has the capability to pass voice and data messages over any of the channels of the pool; and the ASCC, the ASET, and the avionics have the ability, on line, to detect message-mode (voice or data) information and to effect any modem and processing-equipment switching necessary to complete the communication.

A pilot, wishing to communicate, selects the message mode and the type of processing desired (e.g., channel switching, message for ASCC processing, message switching, multiple-point distribution) through the use of special cockpit keyboard input functions. The avionics, then, automatically performs the functions necessary to establish the desired channel connection.

Ground users employ a medium-speed data circuit to notify the ASCC of the mode and processing desired as well as to send and receive data messages. Voice interconnections are made by channel switching in the ASCC.

As in Concepts 1, 2, 3, and 4, one-way return channels are provided to allow rapid-access emergency alerting.

The operation of the independent surveillance subsystem is similar to that of a poll-and-response data channel except that only the functions necessary to gate and transpond tone-ranging signals and to initiate and collect identification and altitude information are provided.

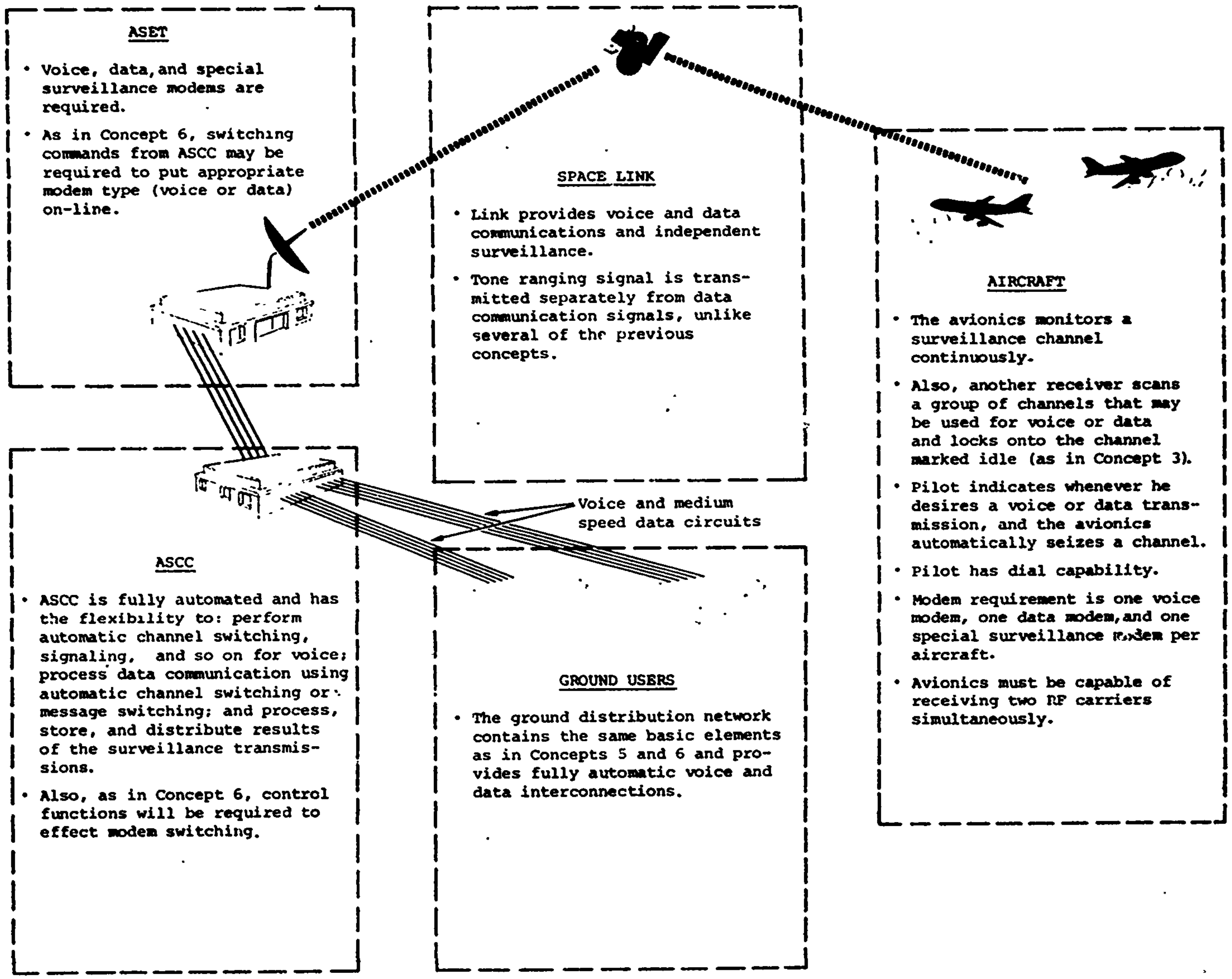


Figure 10. CONCEPT 7 HIGHLIGHTS: VOICE AND DATA COMMUNICATIONS VIA A MARK-IDLE CHANNEL SCANNING SYSTEM AND PROVISIONS FOR INDEPENDENT SURVEILLANCE

The continuous transmission of the ranging signal from an ASET is multiplexed with the low-speed data stream. The avionics continuously receives this multiplexed signal; and, upon detection of its "respond to the surveillance signal" code, it allows the ranging signal to be transponded and returned through both satellites to the ASET, along with data bits representing the aircraft's altitude. This subsystem is fully automatic and operates under the control of automatic processing equipment in the ASCC. Data information resulting from the processing of the returned ranging signals is sent to ground users on a store-and-forward basis.

2.3.2 Technical/Operational Factors Associated with the Seven Concepts

In association with the specification of the seven concepts, a number of technical and operational factors have been identified that provide insight into the kinds of operational uncertainties that may require testing during the T&E program. These factors and the concepts that are associated with them are described briefly in the following paragraphs.

2.3.2.1 Analysis of Voice-Channel Access Techniques

Automatic and manual seizure methods are being considered for access to return-voice channels. There will be varying degrees of success in the implementation of seizure after listening, seizure after listening using re-broadcast, and seizure on the basis of channel-status indications. In fact, it is not known whether a seizure-after-listening technique is feasible in a satellite environment since the pilot will have no knowledge of conversation that could be taking place on his assigned return channel. It is also not known how much conditions will improve in terms of potential interference when rebroadcast (retransmission of return-channel information over the associated forward channel by a cross-patch network in the ASCC) or channel-status-indication techniques are introduced. A comparative evaluation of Concepts 1, 2, 3, and 4 during the T&E program will help to resolve these uncertainties. Also, within the framework of these concepts, additional features such as calling at random over a supervisory channel may be evaluated.

2.3.2.2 Mark-Idle Channel Scanning

While channel scanning is inherently suited to a time-division multiple-access (TDMA) system, its benefit is uncertain in a frequency-division multiple-access (FDMA) system because of the "dwell time" required to tune, acquire, and sample each channel in the scan. In addition, it is not fully known at this time what effect simultaneous and near-simultaneous (occurring within the round-trip propagation delay time) attempts to seize a channel will have on channel-scanning operations. A scanning protocol, called mark-idle channel scanning and used often in automated land mobile systems, has been proposed as a potential way to minimize dwell time and interference effects. Appendix B describes this protocol. Testing during the T&E program will be necessary to determine the potentiality of this operating scheme. Concepts 3 and 7 employ mark-idle channel scanning.

2.3.2.3 Poll-and-Response Data Channels

The poll-and-response data channel, a critical backbone of several viable concepts, has the potential of providing a great deal of system flexibility in terms of delay times, polling intervals, forward and return channeling arrangements, and operational usage, among others. This flexibility, however, creates the need to analyze the trade-offs that may be exercised to optimize the utility of this subsystem, as discussed in Appendix C. During the T&E program, the range of benefits of the poll-and-response data channel should be evaluated extensively. Concepts 4, 5, 6, and 7 utilize, in various forms, a poll-and-response subsystem.

2.3.2.4 Rapid Access for Emergency Communications

For any defined concept, special attention should be given to how a pilot alerts a ground facility of an emergency condition in near-real time. Several methods are being discussed: tone-penetration on a working channel; special one-way return channels for emergency alert; special two-way channels for full emergency communication; and, for data, specially allocated time slots through which any aircraft can respond with an emergency indication. All of these are worthy of evaluation. Data on the certainty of the technique (i.e., could one ever overlook an emergency?) and on the response time for initiating and obtaining a response to an emergency should be collected for all these techniques and for as many concepts as appropriate.

2.3.2.5 Analysis of Multiple Return Channels Associated with One Forward Channel

While the conventional means of conducting two-way communication is to pair one forward channel with one return channel, for air-ground-air communications via satellites, it will be important to investigate the potential of increasing overall acceptable channel utilization by pairing one forward channel with two or more return channels. Two factors working together make the multiple-paired-channel philosophy attractive. First, it has been found that a great deal of the air-ground-air communication time is spent sending information from the aircraft to the ground (see the worksheets of Appendix F in Volume I for a quantification of this situation). Second, it is generally known that less dc power is required in the satellite to transpond air-to-satellite-to-ground information than to transpond ground-to-satellite-to-air information of equal quality. Therefore, pairing of one forward channel with several return channels may improve channel efficiency. This philosophy should be tested for all concepts, and its benefit in each case should be determined during the T&E program.

2.3.2.6 Analysis of Avionics Simultaneous-Receive Requirements and the Ability to Coordinate Simultaneous Responses Over One Transmit Carrier

Concepts 4 and 7 will require the capability of two simultaneous-receive carriers, and in Concepts 5 and 6 there may be advantages in having

a simultaneous milti-carrier receive capability, Moreover, while Concepts 1 and 2 do not require similtaneous-receive carriers, it is possible that the overall aceeptable channel utilization can be increased by allowing avionic equipment to monitor more than one recieve channel. In conjunction with these considerations, however, all work has supposed a one-carrier transmit capaiblity for all configurations.

Therefore, there are two issues that must be examined during the T&E program for almost any concept. One is the benefit of simultaneous-receive functions, and the other is the techniques that will best handle the situation when reponses to simultaneously received signals are presented to the avionics' one-carrier transmit circuitry at the same time. Situations that could occur are two or more voice responses; one voice and one or more data responses; and two or more data responses. The techniques that can reasonably be used to coordinate each of these classes of responses will be different. Moreover, evaluation may show that a multi-carrier transmit function is the best solution.

2.3.2.7 Two-Way Alternate Versus Two-Way Simultaneous Operation

Somewhat similar to the issues listed above is the issue of whether it is necessary or desirable to be able to receive one carrier and transmit one carrier simultaneously. Two-way alternate operation (half duplex) implies that an equipment can receive or transmit, but not simultaneously. This can be called push-to-talk operation. Two-way simultaneous operation, on the other hand, is full duplex, giving the simultaneous receive and transmit capability but requiring independent receive and transmit functions and a duplexer network. Operationally, two-way alternate means that continuous monitoring is not actually possible. There will be times (whenever the avionic equipment is transmitting) when a signal cannot be received. The disadvantages of two-way alternate operation are uncertain for a satellite environment at this time, and they may vary from concept to concept. It is therefore important to test both ways of operation for each concept during the T&E program and to collect data that indicate their relative advantages.

2.3.2.8 Mix of Voice and Data Message Types

Two issues are associated with the mixing of voice and data messages: the technical consequences of transferring analog and digital information intermixed on the same channel and the operational value of digitizing messages as opposed to transferring them by voice. The first issue is being investigated as part of current technology testing and may continue as part of the technology testing of AEROSAT. However, this is not the prime issue even though its introduction may have some operational impact. The concern here, then, is the merit of putting information into standard formats, especially a digital format. For example, is it more advantageous to send flight-plan information by free-text voice, abbreviated (coded format) voice, or digital means? These decisions will depend heavily on the degree of automation employed by ground facilities and avionics and on pilot and controller workload. In many cases, the decisions may be based on subjective as well as quantitative data. During the evaluation of Concepts 6 and 7, it

will be important to try a variety of different mixes of voice and data and to determine their subjective and quantitative merits. This need is exemplified by the cross correlation between several scenarios and Concepts 6 and 7 (see Table 2).

2.3.2.9 Demand-Marked or Pre-Marked Voice and Data Channels

In Concepts 6 and 7, two basic ways of allocating channels for voice and data transmissions should be considered. In the first way, one group of channels is marked for voice and a different group is marked for data. Whenever a user requests a channel, the ASCC selects from one group if it is a voice request and from the second group if it is a data request. This allocation method can be called "premarked" voice and data channels. The second way is to dynamically mark a channel for voice or data each time there is a demand for its use. This method can be called demand-marked voice and data channels. A demand-marked allocation method undoubtedly provides more channel-management flexibility and leads to the more efficient utilization of channels, but it also places greater demands on ground facilities in terms of equipment quantity and control requirements. For example, if the system consists of 10 forward and 10 return channels and a pre-marked allocation is used, 5 for voice and 5 for data, then 5 voice modems are required to exercise the system fully. On the other hand, if demand-marked allocation is utilized, then 10 voice modems and 10 data modems are required to achieve the full flexibility allowed by demand-marking. In practice, combination of voice and data modems providing something less than full flexibility may be acceptable. This would depend on the relative mix of voice and data anticipated. The second expense of demand-marked allocation is the necessity to switch the correct modem "on line" each time a channel is assigned for use. Thus the trade-off in benefits between pre-marked and demand-marked channels and, for demand-marking, the best combination of voice and data modems in light of anticipated loading are important issues in the evaluation of systems offering both voice and data communications.

2.3.2.10 System Entry/Exit Procedures

For all concepts evaluated, special attention should be given to the way aircraft enter and exit the system's service area. Two classes of system entry, normal and pop-up, must be dealt with. Normal entries are those anticipated by ATC (i.e., known aircraft entering the AEROSAT coverage area), whereas pop-up entries occur whenever unanticipated aircraft appear at the coverage area's boundary. Provisions must be made for both of these types of entries. For voice, a universally published entry-calling frequency may be used to accommodate normal and pop-up entries. In a primarily data environment, special polling procedures may be established to handle normal entries, and special time slots may be used to allow pop-up aircraft to alert the ground to their presence. In addition to these provisions, procedures for conducting hand-offs between control areas and provision for aircraft exiting from the system and the subsequent cancellation of any data files associated with those aircraft will be important. During the T&E program, trade-offs should be conducted as part of each concept evaluation to determine the optimum method of handling aircraft entries, handoffs, and exits.

2.3.2.11 Queuing Considerations

A discussion of technical and operational factors associated with operational concepts would not be complete without concern for the queuing that may occur and the effects that concept protocols may have on queuing, and thus on the efficiency with which the system's resources can be used. A number of factors combine to specify the maximum utilization that should be allowed on each channel. These include acceptable response (waiting) time criteria, the distributions of message interarrival times and message durations, the dispatching discipline (e.g., first come-first serve or priority dispatching), certain error-protection techniques such as automatic repeat request (ARQ), the concept protocol itself, and the possible disallowance of queues. Utilization, in conjunction with anticipated peak communication loads offered by the system, in turn specifies the number of channels required. Consequently, the accuracy with which the number of channels that should be provided by the operational system can be specified will be directly influenced by the ability to collect sufficient data in each of the above areas for each concept.

2.3.3 Suggested Test Areas Associated With the Seven Concepts

Table 5 delineates suggested test areas that have been identified during the course of the present study and the study of communications requirements for a 1985-2000 operational satellite system. Generally, these test areas have been classified into three types of operational testing. Each type focuses on one of the three main objectives established for the operational concept evaluations.

Demonstration Testing deals with the actual demonstration of techniques, analysis of users' acceptance of and reactions to various techniques, and the development of practical procedures for conducting communications and operating equipment. Results of this type of testing should provide sufficient procedural information on the use of the operational concepts recommended such that standards and recommended practices (SARPS) can be developed. Subjective data that may be used as part of the analysis of system trade-offs will also be collected as part of this testing.

Data-collection testing focuses mainly on the development of a data base for determining the number of channels that should be provided by the operational system. Quantification of the queuing considerations discussed in Section 2.3.2.11 is of major importance here. For a further description of how these elements relate to the calculation of satellite channel requirements, see Sections 5.1 through 5.4 of Volume I of this report.

The test areas given under Trade-off Testing are concerned with the selection of preferred operating techniques and equipment subsystems. Together with supporting data from the data-collection testing and the subjective data collected as part of demonstration testing, these trade-off tests will provide the basis for recommendations as to which operational concepts should be implemented in the operational system.

While the details of conducting tests in each of these areas are far from complete and the areas identified are not exhaustive, their identification at this time should be useful in planning further study efforts necessary to prepare for actual operational testing.

Table 5. SUGGESTED TEST AREAS ASSOCIATED WITH THE SEVEN CONCEPTS							
Test Area	Concept						
	1	2	3	4	5	6	7
A. DEMONSTRATION TESTING							
1. Pilot and Crew Acceptance/Performance Tests							
a. Seizure after listening access	X			X			
b. Seizure after listening access using rebroadcast	X			X			
c. Seizure on the basis of channel status indications		X		X			
d. Automatic channel access protocol			X		X	X	X
e. Input/output devices							
(1) Channel status indicators		X	X	X			
(2) R/T control unit			X		X	X	X
(3) Control/display unit						X	X
(4) Cockpit printer						X	X
(5) Cabin display/keyboard						X	X
f. Emergency alert measures							
(1) Penetrating tone	X	X	X	X			X
(2) One-way return emergency voice channel	X	X	X	X			X
(3) Two-way emergency voice channel	X	X	X	X			X
(4) Alerting via data link					X	X	
2. ASCC Communicator Acceptance/Performance Tests							
a. Information processing							
(1) Voice channel phone patches	X	X		X			
(2) Voice-to-voice relays	X	X		X			
(3) Voice-to-teletype relays	X	X		X			
b. Handling of emergency alerts							
(1) Penetrating tone response	X	X		X			
(2) One-way return emergency-voice-channel response	X	X		X			
(3) Actions using two-way emergency voice channel	X	X		X			
c. Processing of normal and pop-up entries	X	X		X			
d. Shared forward/multiple return channel processing	X	X		X			
e. Priority communication processing	X	X		X			
3. Ground User Acceptance/Performance Tests							
a. Voice-channel access	X	X	X	X	X	X	X
b. Data-channel access						X	X
c. Query/response actions with ASCC computer				X	X	X	X
4. ASCC Automation							
a. Automatic dial processing			X		X	X	X
b. Priority call processing			X		X	X	X
c. Queue administration				X	X	X	
d. Ability to establish and maintain poll lists and administer polls				X	X	X	X
e. Processing of normal and pop-up entries			X	X	X	X	X
f. Data file cancellation upon aircraft exit				X	X	X	X
g. Automatic hand-off capability				X	X	X	X
h. Surveillance information processing and distribution to ground users				X	X	X	X
i. Multiplexing of data-link communication signals and surveillance ranging signals for transmission on one RF carrier				X	X	X	
j. Use of selectable polling rates on the basis of aircraft speed and location				X	X	X	X
k. Use of variable block lengths by transmitting length information over the data link					X	X	
l. Administration of demand-assigned channels							
(1) Voice only			X		X		
(2) Pre-marked voice and data						X	X
(3) Demand-marked voice and data						X	X
m. Coordinated processing of demand voice, demand data, and surveillance information						X	
n. Automatic emergency alert processing			X		X	X	X
5. Avionics Automation and Processing Capability							
a. Auto-tune capability using ground control					X	X	X
b. Automatic channel-seizure capability			X		X	X	X
c. Processing of coincidental return transmissions							
(1) Two voice responses	X	X					
(2) One voice/one data response				X	X	X	X
(3) One data/one surveillance						X	X
(4) One voice/one data/one surveillance						X	X
d. Ability to collect, buffer, and transmit peripheral data information				X	X	X	X

(continued)

Table 5. (continued)

Test Area	Concept 1	2	3	4	5	6	7
B. DATA COLLECTION TESTING							
1. ASCC Queue Size as a Function of Channel Utilization							
a. Ground user requests in queue	X	X		X	X	X	
b. Pilot/crew requests in queue					X	X	
2. Channel-Access Delay Times as a Function of Channel Utilization							
a. Ground user delay distribution	X	X	X	X	X	X	X
b. Pilot/crew delay distribution	X	X	X	X	X	X	X
3. Queueing Delay Times as a Function of Channel Utilization							
a. Ground user delay distribution	X	X		X	X	X	
b. Pilot/crew delay distribution					X	X	
4. Distribution of Blocked Calls as a Function of Channel Utilization							
a. Ground user distribution			X				X
b. Pilot/crew distribution	X	X	X	X			X
5. Service Times as a Function of Channel Utilization							
a. Ground user initiated	X	X	X	X	X	X	X
b. Pilot/crew initiated	X	X	X	X	X	X	X
6. Effects of Various Dispatch Disciplines on Acceptable Channel Utilization							
a. First come-first serve	X	X	X	X	X	X	X
b. Priority head of line					X	X	
c. Priority interrupt	X	X	X	X	X	X	X
7. Effects of Various Error Protection Techniques on Acceptable Channel Utilization							
a. Error correction				X	X	X	X
b. Automatic repeat request				X	X	X	X
8. Number of Aircraft Handled by:							
a. One channel	X	X	X	X	X	X	X
b. One communicator	X	X		X			
c. One air traffic controller	X	X	X	X	X	X	X
9. Effects of Various Multiple-Return/One-Forward-Channel Arrangements on Channel Utilization	X	X		X	X	X	
10. Throughput Capability of Poll-and-Response Data Link for:							
a. Various polling rates					X	X	
b. Various block lengths					X	X	
c. Different overhead schemes				X	X	X	X
C. TRADE-OFF TESTING							
1. Selection of Preferred Return-Voice Channel-Access Technique	X	X	X	X			
2. Channel-Busy Versus Channel-Idle Status Indication		X		X			
3. Two-Way Alternate Versus Two-Way Simultaneous Operation		X	X	X	X	X	X
4. Selection of Preferred Simultaneous Receive/Transmit Requirements for Avionics	X	X		X	X	X	
5. Selection of Preferred Emergency Alerting Scheme	X	X	X	X	X	X	X
6. Selection of Preferred Multiple-Return/One-Forward-Channel Arrangement	X	X		X	X	X	
7. Dependent, Independent, or Dependent and Independent Surveillance				X	X	X	X
8. Selectable Versus Fixed Polling Rates				X	X	X	X
9. Variable Versus Fixed Block Lengths					X	X	X
10. Multiplexed or Separately Transmitted Ranging Signals				X	X	X	
11. Preferred Data Rate				X	X	X	X
12. Pre-Marked Versus Demand-Marked Voice and Data Channels						X	X
13. Selection of Message Types That Should be Digital and Those That Should Remain in Voice						X	X

CHAPTER THREE

THE MINI-ASET CONCEPT

Small and limited-capability earth terminals known as Mini-ASETs have been advocated for inclusion in the AEROSAT T&E program. These terminals could provide communications access to the AEROSAT system in areas where it is undesirable, impractical, or impossible to use conventional communications lines to the ASCC. The Mini-ASET could be used to provide communications between the Mini-ASET site and an aircraft or between the Mini-ASET and a second fixed point (i.e., an ASET or another Mini-ASET). The first of these two applications is consistent with the internationally accepted role of an aeronautical satellite and is the subject of this chapter. The issue of the possible use of a Mini-ASET to provide "off peak" point-to-point communications is discussed in Section 4.3.1 of Chapter Four.

The Mini-ASET concept was agreed upon well after the system engineering was performed for the basic AEROSAT system. As a result, the Mini-ASET suggested for use in the T&E program will be a technical expedient consisting of a simple earth terminal possessing essentially the same capability as a nonmobile set of AEROSAT avionics. In the following subsections, the discussion is expanded beyond a description of the Mini-ASET planned for the T&E program to provide a framework for evaluating the general concept of a Mini-ASET. The overall rationale for a Mini-ASET is presented, and this is followed by a discussion of the general categories of communications that could be handled by a Mini-ASET. Then, without regard to the specific Mini-ASET design being proposed for the AEROSAT T&E program, the various operational configurations that could be associated with a Mini-ASET are discussed. Finally, the current Mini-ASET design is described, as are the test areas that should be considered in the development of specific test plans for evaluating the Mini-ASET concept.

3.1 REASONS FOR CONSIDERING THE MINI-ASET CONCEPT

There are primarily two reasons for considering the concept of a small, low-density, economical earth terminal for aeronautical satellite applications:

1. The Mini-ASET may provide the only reasonable way for some potential users to gain access to the satellite network.
2. Network optimization may be enhanced by considering the Mini-ASET as a low-density alternative to an ASCC/ASET installation.

Once the backbone of the satellite system (i.e., ASCCs, ASETs, and satellites) is designed, users planning to gain access to it will have to consider three factors in deciding what communications facilities should be used to provide the necessary access: the types and service areas of available communications, the cost of alternative interconnect arrangements, and the reliability of existing communications. If the options associated with any of these factors prove to be unsatisfactory, the user will probably not participate until conditions improve. The extreme case, of course, is the situation in which no communications circuits are available to provide the user with the proper interconnection. In this situation, the user is unable to participate without a Mini-ASET. The Mini-ASET may have the potential for justifying the participation of certain users who would otherwise find it unreasonable or impossible to participate.

A second reason for considering the Mini-ASET concept is its potential for enhancing the overall cost-effectiveness of the satellite system backbone. Low-cost, low-capacity earth terminals are being developed to meet minimum capacity requirements at a low cost in many instances throughout the world, and they appear to have a promising future (see *Microwave Systems News*, June/July 1975, Vol. 5, No. 3, pp. 19-42). As part of the aeronautical satellite system backbone, the Mini-ASET may prove to be the best means of serving certain geographical areas. This will depend on the combined effect of a number of network optimization factors:

1. Geographical concentration of users
2. Earth-terminal capacity requirements
3. Overall network cost
4. System performance requirements
5. Possible system control problems

For example, a system consisting of one ASET and two strategically located Mini-ASETS might prove to be more cost-effective than two ASETs.

During the T&E program, it will be important to collect data that will demonstrate the merit of the Mini-ASET concept; it will be even more important to take advantage of these demonstrated Mini-ASET benefits during the engineering of any eventual operational system.

3.2 SPECIFIC POTENTIAL APPLICATIONS OF THE MINI-ASET CONCEPT

Three broad categories of operation were examined during the study to identify potential communications applications that might utilize the capabilities offered by a Mini-ASET concept:

1. Search and Rescue Operations (SAR)
2. Air Traffic Control (ATC)
3. Company Operational Control

It was recognized that much more research would be required to provide definitive results on the most desirable specific applications of the Mini-ASET. Consequently, only issues that may have a bearing on the scope of the T&E test planning are discussed in this report. It is suggested that, as part of the ongoing T&E test planning, in-depth survey techniques be employed to develop case histories and other data on the nature of present communications problems and the requirements for their solution. From these, it is possible to determine more specifically the potential applications associated with the Mini-ASET concept.

In the following paragraphs, currently identified issues associated with the three areas of examination are described. It is hoped that these will be used as starting blocks for additional work in these areas.

3.2.1 Deployment of a Mini-ASET in Support of Search and Rescue (SAR) Operations

In performing its search and rescue (SAR) mission, the Rescue Coordination Center (RCC) must be able to establish and maintain good communications with a number of support organizations as depicted in Figure 11. The RCC must collect and disseminate a variety of information for the following purposes:

- To establish the location of the distress aircraft
- To establish the location of aircraft and vessels that may be able to help in the search and rescue (called vessels of opportunity)
- To determine weather conditions in the SAR area of operation
- To coordinate activities with the last air traffic control facility to have contact with the distress aircraft and with the rescue support elements
- To plan and execute the evacuation of survivors

The AEROSAT system may be able to support SAR operations effectively by providing a common vehicle for conducting its diverse communications and by expediting and improving the accuracy of some of the information required by the RCC.

The Mini-ASET may be an ideal candidate for providing the means for RCCs to access the AEROSAT system. Being deployable, it can provide for quick-reaction RCC operation. The RCC could actually be mobile and conduct its required function near, or on the way to, the scene of the incident. The Mini-ASET may also be able to reduce the communications cost associated with RCC connectivity requirements since its use would eliminate the requirement for full-period circuits to a number of locations.

Further supporting the usefulness of the AEROSAT system to SAR operations is the ASCC's ability to perform position-fixing on the basis of surveillance information and the intended interface with meteorological offices by means of which detailed weather information can be rapidly forwarded to the RCC.

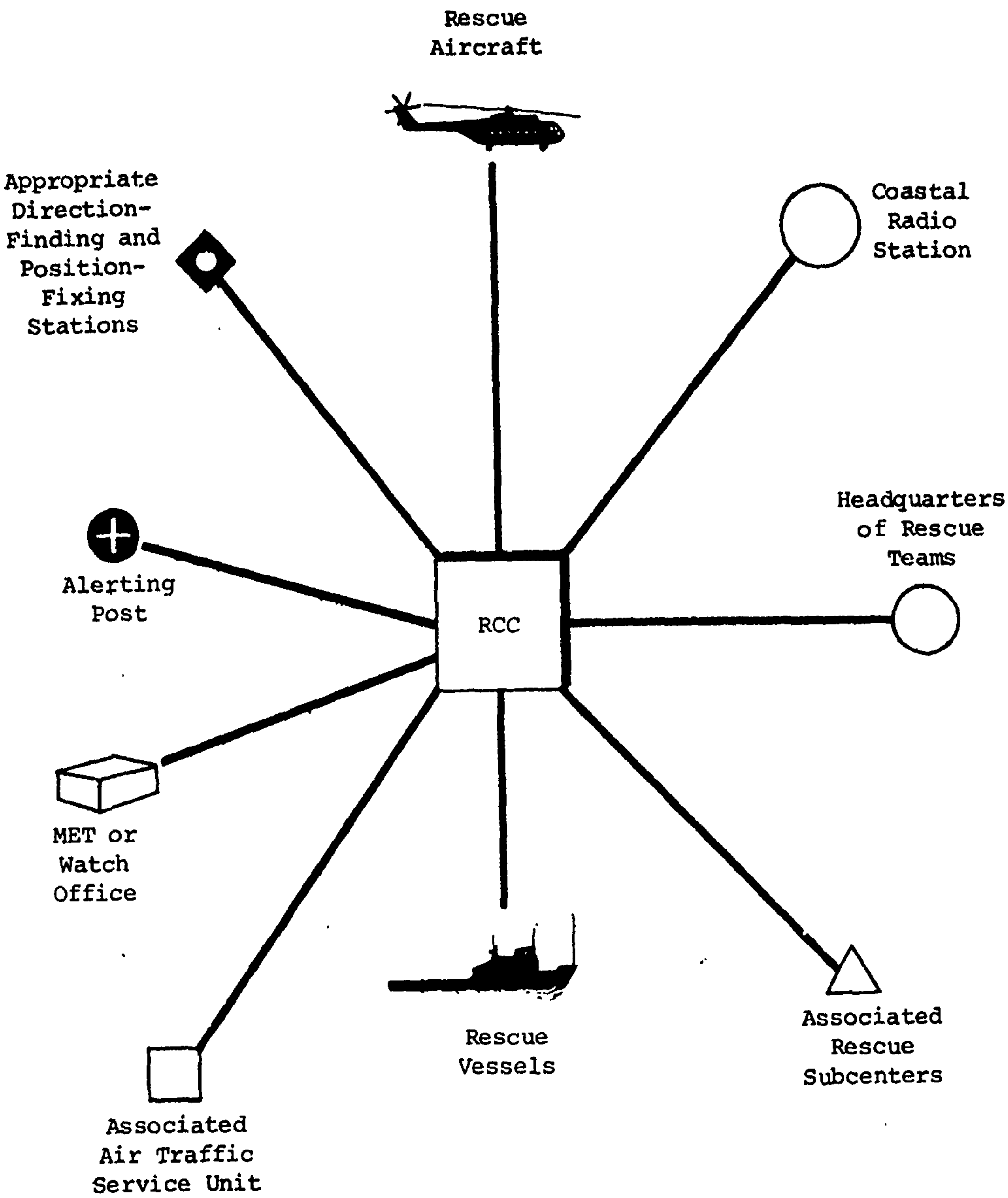


Figure 11. REQUIRED POINTS OF COMMUNICATION FOR A RESCUE COORDINATION CENTER (RCC)

Because of this potential role in SAR operations, it is recommended that tests be conducted during the T&E program to demonstrate the operation of the Mini-ASET during simulated (or actual) emergencies.

3.2.2 The Mini-ASET as a Basic Air Traffic Control (ATC) Element

As an ATC element, the Mini-ASET would consist of a one-position ATC unit that would rely heavily on the automation capabilities of a distant ASCC or larger ATC facility. Flight data processing--including flight-plan data, amendment and aircraft activation data, surveillance information, automatic transfer, and boundary sensing--would be conducted at the distant facility and transferred to the low-density unit as required. The low-density unit would then exercise control of aircraft within its defined airspace on the basis of the information received from the remote ASCC.

However, an important drawback to this application is the dichotomy associated with the centralization of ATC functions. On one hand, emphasis is being placed on the ability of the satellite to reduce the number of control areas to a minimum so that the trend toward increased user charges will be offset.* On the other hand, a number of political-economic factors suggest that control areas cannot readily be centralized. The role of the Mini-ASET in ATC operations is thus in doubt since its introduction would support the present decentralization of ATC as opposed to AEROSAT's intended goal of centralization.

The Mini-ASET can be regarded as a potential way to minimize the impact of decentralized ATC if, in the end, decentralization must be maintained. For example, the Mini-ASET would permit decentralized oceanic centers to share the surveillance processing capability of the centralized ASCC and thereby eliminate unnecessary duplication of effort.* The Mini-ASET may also be employed successfully as a mobile ATC control facility to be used during emergency situations where a temporary communication facility is required. In this case, its role would be similar to that discussed in Section 3.2.1. Therefore, it is believed that the Mini-ASET should be tested as a fixed and a mobile low-density ATC center.

3.2.3 The Mini-ASET in Support of Company Operational Control

During the study of the communications requirements for a 1985-to-2000 operational aeronautical satellite system, particular attention was given to the kinds of company aeronautical mobile messages, present and new, that might be transferred via the satellite system. Those identified were classified in five general areas:

- Flight Operations
- In-Flight Maintenance Support
- Flight Management/Logistics
- In-Flight Passenger Services
- Aircraft On-Ground Services

---

*See *Study of Oceanic Airspace and Ground Network Configurations in Satellite Systems,* Stanley A. Klein, Computer Sciences Corporation, Falls Church, Va., Final Report, Report No. FAA-RD-73-59, July 1973.

As part of this effort, a number of airlines were interviewed in an attempt to isolate particular situations in which satellite communications might be uniquely advantageous, as well as to understand the kinds and priorities of company communications conducted over HF today. In the questionnaire used to guide interviews, one question dealt directly with the potential use of small, remote earth terminals.

As a result of this work, several factors are now known that will have a bearing on the use of Mini-ASETs in support of company operational control:

- There are basically two types of operators: those who operate in a "dispatch mode" and those who operate in a "nondispatch mode". The communications required to support the two are distinctly different. American air carriers are typically dispatch operators, principally because of the FAA requirement for airlines to know where their aircraft are at all times. Dispatch operators require a good deal more communications than the nondispatch operators. In fact, nondispatch operators request that their pilots contact the company only in cases of airframe equipment failure or when there are significant deviations in the flight plan or normal ground time. While a dispatch operator may have a need to consider digital communications for routine company messages, the nondispatch operator has virtually no need for routine company communications, and thus the number of digital communications generated by a non-dispatch operator would be small.

- The most vital company messages concern flight operations and in-flight maintenance support and, to a lesser degree, aircraft on-ground services. These messages are primarily transferred between pilots and home offices or dispatch units. The dispatcher, or some other company official in the case of nondispatch operators, in turn coordinates with other facilities (e.g., meteorological offices and maintenance facilities) as necessary. Only on rare occasions will a pilot require conversation directly with these other facilities. When he does, however, the communication is almost always extremely critical.

- For dispatch operators, a large part of what several airlines call "data collection" communications (e.g., position reports, OOOI reports, weather reports, and fuel messages) could be digitized.

- Communications are particularly critical whenever there is an aircraft maintenance problem, an unusual flight operation condition, or a requirement for performance of a special service upon landing, and efficient and timely attention to the matter can prevent (1) a significant change in flight scheduling or (2) an unusually long ground time or maintenance turnaround time. These critical company messages are virtually always voice communications, and they are usually quite long.

On the basis of these factors, it appears that one or more of the following conditions would have to be present to justify considering the use of a Mini-ASET for company operational control purposes:

- A company, or companies, have a dispatching or home base facility in the vicinity of the proposed Mini-ASET location.
- The proposed location is a point of known coordination or scheduling problems, or it is a point at which time-critical scheduling is necessary, e.g., a high-density circuitous route point, or a major aircraft-turnaround point.
- The proposed Mini-ASET service would have to be economically competitive in cases where alternate means of communications, such as HF or VHF, were available also.

In view of the potential benefits of the Mini-ASET to company communications, it is recommended that the T&E program provide Mini-ASETs for company communications from selected remotely located cities served by one or more dispatch-oriented airlines.

3.3 SYSTEM OPERATIONAL CONFIGURATIONS ATTAINABLE THROUGH THE USE OF THE MINI-ASET TO PROVIDE AIR-GROUND-AIR COMMUNICATIONS

The Mini-ASET site may communicate with the aircraft either through a direct satellite relay as shown in Figure 12a or through an indirect relay that uses the ASET/ASCC as shown in Figure 12b. Generally speaking, any of the seven communications operating concepts developed in Chapter Two could be employed with either of the two Mini-ASET communications routings.* Therefore, to facilitate the aircraft-to-Mini-ASET-to-aircraft communications, the communications concept chosen for Mini-ASET operation should be made compatible with the basic (i.e., aircraft to ASET) operational concept that is ultimately selected. In all cases it is assumed that the Mini-ASET-to-aircraft communications channels would be controlled by or coordinated through the ASCC. This could entail either continuous reallocation of channels by the ASCC for basic and Mini-ASET communications or the use of semi-permanent channel assignments by the ASCC for Mini-ASET use.

Subsections 3.3.1 and 3.3.2 describe two methods for implementing each of the configurations depicted in Figure 12.

3.3.1 Mini-ASET/Aircraft Communications via Direct Satellite Relay

Conceptually, the most direct method for obtaining communications between Mini-ASET and aircraft would be to use the satellite as a transponder that pairs Mini-ASET channels with the channels assigned to aircraft. This would require some additional modes of satellite operation that were not considered in the original satellite design (the original design provided only for ASET-to-aircraft communications).

*Section 3.3.2 is a discussion of a store-and-forward mode of operation that might not be suitable for voice communications and would therefore be inconsistent with some of the concepts set forth in Chapter Two.

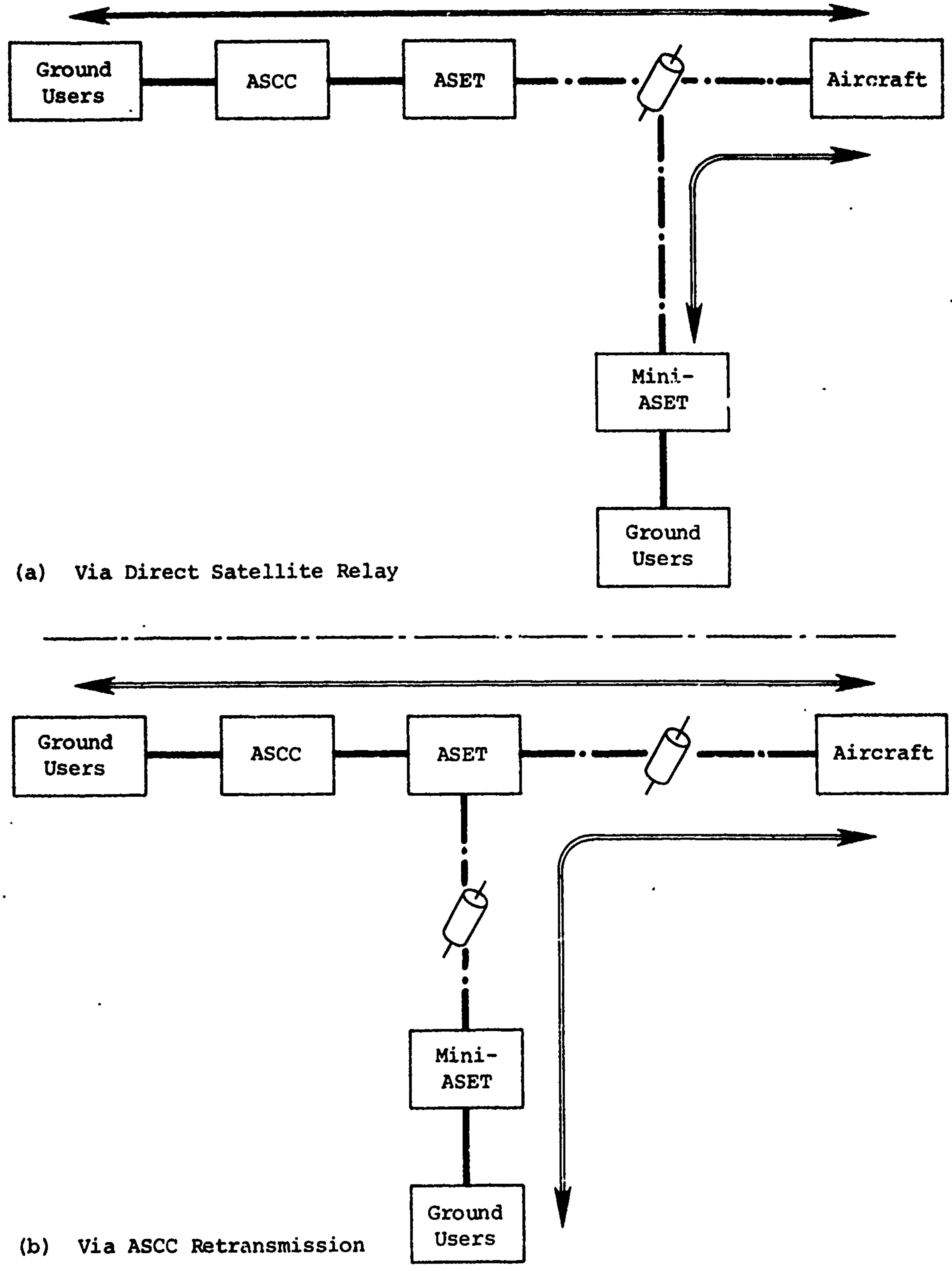


Figure 12. CONNECTIVITY FOR MINI-ASET/AIRCRAFT COMMUNICATIONS

A Mini-ASET could be designed to operate in this mode at C-Band (i.e., the band used by the ASET) or VHF or L-Band (the bands being evaluated for aircraft use). From the system-manangement standpoint, it will probably be more efficient to operate at C-Band because at C-Band the Mini-ASET's connectivity requirement is exactly the same as the requirement of the ASET -- that is, C-Band to L-Band (or VHF) and L-Band (or VHF) to C-Band, respectively, for the forward and return channels. This permits the shared use of forward and return channels for ASET/aircraft and Mini-ASET/aircraft communications. Of course, from a technical design standpoint, it would be necessary to consider the cost and antenna problems inherent in Mini-ASET C-Band operation.

If, on the other hand, the Mini-ASET operates at L-Band (or VHF), one of the following would have to be designated:

1. C-Band/L-Band (or VHF) channels exclusively for ASET/aircraft communications and separate L-Band/L-Band channels for exclusive Mini-ASET/aircraft communications on a long-term basis
2. Common satellite-to-aircraft channels that are switched between C-Band (for the ASET) and L-Band (for the Mini-ASET) on a demand basis to establish the necessary C-Band/L-Band and L-Band/L-Band channels.

The first of these modes sacrifices the shared use of channels, while the second imposes additional design requirements on the satellite. Both add to satellite cost and satellite-control design requirements. However, the L-Band (or VHF) Mini-ASET does permit avionic equipment to be used almost directly as a remote earth terminal.

The Mini-ASET would have to allocate the use of satellite channels assigned to it to ground users and pilots through a concept of operation that could be virtually identical to any of the basic operational concepts described in Chapter Two. In this regard, the Mini-ASET would function in the same way as an ASCC and ASET combined, but on a much smaller scale. Coordination channels (i.e., C-Band/C-Band or C-Band/L-Band) would be required to link the Mini-ASET to the ASCC/ASET facilities.

In summary, the Mini-ASET operating as depicted in Figure 12a would be considered a low-density earth segment, and its function would be essentially the same as those defined for the ASET and the ASCC. To minimize the cost and complexity of this type of Mini-ASET operation, it could be desirable to consider potential ways in which some of these functions could be remotely processed at an ASCC and transmitted to the Mini-ASET over a channel that would be used for ASET/Mini-ASET coordination.

3.3.2 Mini-ASET/Aircraft Communications via ASCC Retransmission

The second system operational configuration obtainable by using the Mini-ASET and providing air-ground-air communications is based on an indirect method of providing Mini-ASET/aircraft communications. Communications originating from ground users served by Mini-ASETs are first routed via

a satellite relay connection to an ASET and subsequently to the associated ASCC. They are then retransmitted from the ASCC to an aircraft via a second satellite relay connection. In this scheme the Mini-ASET appears to be simply another aircraft, but one that is allowed to communicate with other aircraft through a pairing of channels at the ASCC. This scheme, for duplex operation, would consist of the following:

1. A two-way link connection between the Mini-ASET and the satellite
2. An appropriate interconnection within the satellite
3. A two-way link connection between the satellite and the ASET

Then, at the same time these connections are performed, or at a later time, the following would also occur:

4. A two-way link connection between the ASET and the satellite
5. An appropriate interconnection within the satellite
6. A two-way link connection between the satellite and the aircraft

For aircraft-to-Mini-ASET communications, the sequence of events would be reversed.

The end-to-end ASCC-retransmission connection can be implemented by two methods. In one method there is a direct communications path from a user served by the Mini-ASET to an aircraft. This occurs when the above-listed steps 1, 2, and 3 are performed in parallel with steps 4, 5, and 6 to form a two-forward-channel (ground-to-air) and two-return-channel (air-to-ground) communications capability. This type of connection would be required for conventional voice conversations between ground users served by Mini-ASETs and aircraft, and it may be desired for some Mini-ASET/aircraft data communications. (Hereinafter this type will be called a "concurrent ASCC-retransmission" communication.)

The second method of forming the end-to-end ASCC-retransmission connection is on a store-and-forward basis. This type of connection is obtained when steps 1, 2, and 3 above are performed and information is transmitted to the ASCC; the information is buffered or stored in the ASCC for a period of time; and then steps 4, 5, and 6 are performed and the information is forwarded to an aircraft. If a confirmation or response to the communication is required, a reverse store-and-forward connection is used to route information back to the ground user. (Hereinafter this type will be called a "store and forward ASCC-retransmission" communication.) This form of connection would be restricted for the most part to data communications.

In addition to the operationally duplex scheme, one may also consider the use of a single set of L-Band or VHF channels (one forward and one return) and their associated C-Band channels to provide real-time communications between a Mini-ASET and an aircraft on an operationally simplex basis. In this mode, the Mini-ASET and the aircraft would share the use of the link as in push-to-talk communications. In practice, this mode of communication would be acceptable so long as both the Mini-ASET and the aircraft

could access the same L-Band (or VHF) frequency pair yet be far enough from each other so that signals transmitted by one unit (e.g., the Mini-ASET) would not be received directly (not via the satellite) by another unit (in this instance, the aircraft). If direct reception were to occur, there would be mutual interference between the direct signal and the signal which had traversed the satellite.

For Mini-ASET/aircraft communications via ASCC retransmissions, the only practical approach is to design the Mini-ASET for satellite accessing at L-Band or VHF since an unnecessary redundancy of link connections would occur when C-Band was used. When operated in this way, the Mini-ASET will be functionally the same as avionics. Consequently, the advantages of this concept of operation arise from the fact that the ASCC can manage communications to and from Mini-ASETs in the very same way it manages communications to and from aircraft.

The Mini-ASET operating in this fashion would be incorporated into the basic operational concepts (described in Chapter Two) as simply another mobile. The Mini-ASET obtains access to the system by using the same protocols as those defined for aircraft in the descriptions of the seven concepts; in fact, much of the equipment that will comprise avionics can be used to configure the Mini-ASET. These operational factors have led to the currently proposed Mini-ASET configuration.

3.4 CURRENT MINI-ASET DESIGN FEATURES

For the T&E program, the Mini-ASET will be basically a ground-based set of avionics with a ground-user interface capability. It is conceived to be a relatively low-cost earth terminal for testing and evaluating the capability of establishing communications between remotely located facilities and other system users, especially aircraft, through a relay capability that is attainable within the ASCC. The planned Mini-ASET will therefore basically support the ASCC-retransmission mode of operation. The Mini-ASET equipment (see Figure 13) would be similar to that of the Electronic Test Set (ETS) and would consist of L-Band and VHF antenna, transmitter, and receiver sections; a control and processor section; a ground-user interface section; and an input/output section that would consist of display/keyboard, printer, microphone/handset, and recorder/player equipment.

The Mini-ASET will be capable of accessing each satellite in either L-Band or VHF, receiving simultaneously one voice and one data signal at L-Band,* and conducting two-way alternate (half-duplex) and two-way simultaneous (full duplex) communication at L-Band.*

---

*The simultaneous-receive requirement and the requirement for two-way simultaneous operation at VHF are uncertain at this time.

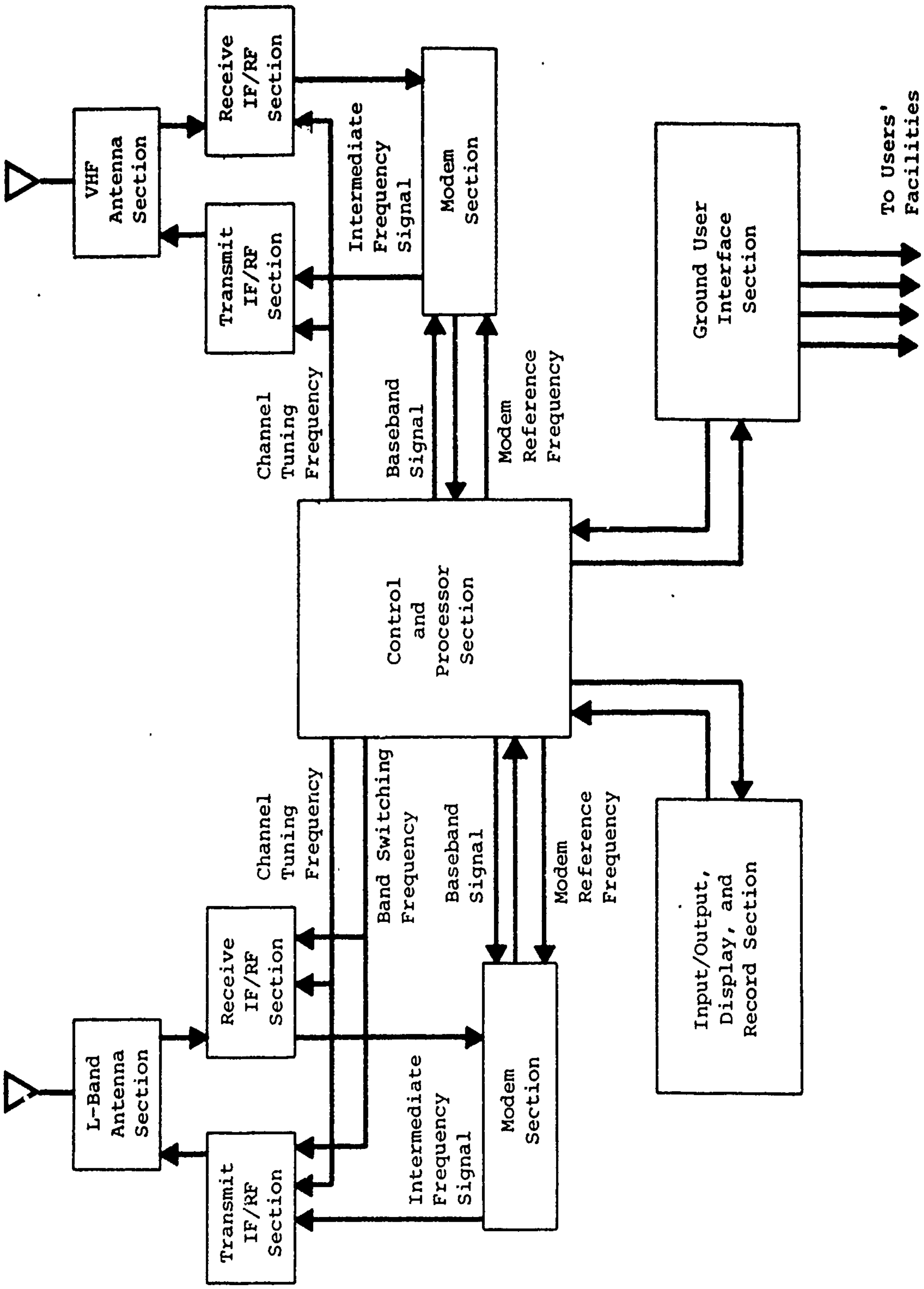


Figure 13. MINI-ASET BLOCK DIAGRAM

3.5 SUGGESTED TESTS FOR THE MINI-ASET CONCEPT

Many of the test areas identified in Table 5 for evaluation of the seven basic operational concepts during the T&E program are applicable to the evaluation of the Mini-ASET concept as well. Conducted in parallel, these tests will provide a relative measure of the operational performance represented by the Mini-ASET concept and that represented by the seven basic concepts. Like the ASCC, the Mini-ASET must be tested to demonstrate its information-processing capabilities and to collect data that will determine the queueing delay time and service time distributions, the effects of certain operational features on channel utilization, and the information-handling capacities associated with the Mini-ASET's processing capabilities.

Three additional series of tests, as identified in Table 6, should be conducted to determine the preferred capabilities and applications of the Mini-ASET, to ensure that the Mini-ASET concept is compatible with each of the seven basic operational concepts, and to reveal any increases in the types and quantity of communications that might have occurred as a result of providing a Mini-ASET capability at remote sites.

In Section 3.3 two potential Mini-ASET operational configurations were described. However, from the currently envisioned Mini-ASET design features, only one of these can be implemented and directly evaluated during the T&E program. This is the configuration that provides a capability for Mini-ASET/aircraft communications via an ASCC retransmission (in Table 6 this configuration has been labeled "Configuration A"). However, either the concurrent or store-and-forward method could be evaluated with the current-design Mini-ASET.

While the other configuration cannot be directly evaluated during the T&E program, a Mini-ASET configuration that accesses the satellite at C-Band can be simulated by configuring portions of an ASET and an associated ASCC to operate as though it were a Mini-ASET accessing at C-Band (this simulated configuration has been labeled "Configuration B" in Table 6). This configuration would coordinate with the distant ASET/ASCC installation via a C-Band/C-Band channel in order to simulate as nearly as possible a Mini-ASET accessing at C-Band. Direct satellite relay using Mini-ASET operation at VHF or L-Band will not be possible during the test program unless the satellite is redesigned.

As shown in Table 6, application testing, capability testing, and compatibility testing should be performed for the two candidate configurations. The application tests will consist of demonstrations of the capability and benefits of Mini-ASETs in real or simulated operations. The application tests should consist of both preplanned communications scenarios and unplanned situations in which potential users are allowed to experiment with the overall utility of the Mini-ASET.

Table 6. TEST AREAS UNIQUELY ASSOCIATED WITH THE MINI-ASET CONCEPT

Test Area	Configuration A	Configuration B
Application Testing		
Mini-ASET for SAR Operations		
Using a Deployable RCC Scenario	X	
Using a Fixed-Station RCC Scenario	X	
Low-Density Mini-ASET, ATC Unit	X	X
Mini-ASET as a Company Dispatch and Coordination Facility	X	
Mini-ASET as a Remote Area Communications Center for ATC and Company Operations	X	X
Capability Testing		
Voice		
Concurrent Transmission	X	X
Store-and-Forward Transmission	X	
Data		
Concurrent Transmission	X	X
Store-and-Forward Transmission	X	
Compatibility Testing		
Integration with Basic Operational Concept 1	X	X
Integration with Basic Operational Concept 2	X	X
Integration with Basic Operational Concept 3	X	X
Integration with Basic Operational Concept 4	X	X
Integration with Basic Operational Concept 5	X	X
Integration with Basic Operational Concept 6	X	X
Integration with Basic Operational Concept 7	X	X

The capability testing will focus on concurrent and store-and-forward types of communications. Concurrent transmissions represent the mode of operation in which the end-to-end connection is established to permit two-way conversational exchanges, and these may be conducted in both configurations. Only for Configuration A is the store-and-forward type of transmission, as defined in Section 3.3.2, necessary. This type of transmission represents an ASCC retransmission wherein there is a time lag between the time an ASCC receives a transmission from a Mini-ASET (or aircraft) and the time it forwards the transmission to an aircraft (or Mini-ASET). Store-and-forward ASCC retransmissions will be well suited for use in conjunction with a poll-and-response type of operation defined for several of the basic operational concepts. Consequently, for applications in Configuration A four transmission modes will be tested, while for applications in Configuration B only the concurrent transmission modes will be tested.

The main advantage of the store-and-forward ASCC retransmission over concurrent ASCC retransmission is that it will probably save channels. This is particularly true for data transmissions. Although unusual, a store-and-forward voice-transmission capability has been suggested. This would consist of a voice transmission from a Mini-ASET (or aircraft) to an ASCC, where it would be recorded on a voice player/recorder unit. At some later time, the recorded voice message would then be relayed to an aircraft (or Mini-ASET). The communication will not, of course, be a two-way voice conversation, but its application will provide a means to transmit a formatted message by voice without the requirement for a two-way end-to-end connection. This may be particularly useful in sending specially formatted voice messages, such as VOLMET, to pilots. The testing of this option should include an operational evaluation of the "human factors" problems of the store-and-forward voice capability.

For the concurrent test cases of Configuration A, both duplex and simplex operational schemes should be evaluated. As discussed in Section 3.3.2, the duplex scheme requires two sets of forward and return channels for concurrent communications, whereas the simplex scheme requires only one set. Of course, the disadvantages of the simplex scheme (e.g., mutual interference and line coordination problems) must be weighed against its potential for reducing the number of forward and return channels required.

For each application, compatibility testing should be conducted to evaluate the ability of the Mini-ASET operating in a particular configuration to perform efficienly in conjunction with each of the basic operational concepts. Data similar to those identified in Table 5 should be collected to determine the operational performance of each Mini-ASET/Basic Operational Concept combination.

CHAPTER FOUR

THE OFF-PEAK SERVICES CONCEPT

During periods of low air-ground-air communications activity, the AEROSAT could potentially support additional types of communications. The off-peak services concept presented herein permits transferring information between ground users and aircraft (i.e., air-ground-air communications) and among ground users (i.e., point-to-point communications) in a manner that would not jeopardize the system's primary purpose of providing aeronautical mobile communications services. The reasons for considering this concept during the T&E program are presented in this chapter, together with a description of the potential applications of the concept and the system resources that may be used to implement the concept. Potential problems associated with the off-peak services are then identified. Finally, the types of tests that should be performed during the experimental phase in order to determine the eventual viability of the concept are outlined.

4.1 CONSIDERATIONS OF OFF-PEAK SERVICES CONCEPT

The need for considering the off-peak services concept during the T&E program is indicated by the following:

1. When used only for aeronautical mobile communications, the satellites will undoubtedly have unused channel capacity during portions of each day as a result of the well-known peaking effect of oceanic air traffic, especially in the Atlantic. The off-peak services concept offers the means for taking advantage of these unused channels.
2. Certain communications associated with the conduct of ATC and company business, while not technically classified as aeronautical mobile communications, are necessary or desirable for the safe and efficient conduct of oceanic aeronautical operations. These communications may be good candidates for transfer via the AEROSAT system at a lower priority than aeronautical mobile communications.

Together, these reasons suggest that during portions of each day communications capacity will be available for use in transferring nonaeronautical mobile communications without changing the safety or effectiveness of the aeronautical mobile communications service. The off-peak services concept has been developed as a means of achieving these other communications

during off-peak periods. The utility of this concept in an operational system will depend on the system's ability to conduct both air-ground-air and point-to-point communications in a suitably coordinated manner; it will also depend on the cost associated with the point-to-point communications. These factors should be investigated during the T&E program. The final decision to implement this concept, however, will depend most directly on the regulatory issues associated with it. These issues will necessarily be world-wide in scope, and their resolution will require international agreement. Since the off-peak services concept will affect the present state of transoceanic point-to-point communications, its implementation will likely draw the attention of international communications common carriers.

4.2 POTENTIAL APPLICATIONS OF AN OFF-PEAK SERVICES CONCEPT

On a non-interference basis with the normal aeronautical mobile communications services -- which permit emergency, direction-finding, flight safety, meteorological, and flight-regularity messages -- the off-peak services concept may offer four nonaeronautical-mobile communications services:

1. *A low-priority air-ground-air communications service.* This service would consist of messages between ground users and aircraft that do not have a high enough priority to be included as part of the aeronautical mobile service. These might include passenger entertainment, public correspondence, aircraft use of ground-based computers, airborne availability of data on the relative positions of surrounding aircraft, direct in-flight position determination, advanced detection and transmission of atmospheric data, flight-crew physiological data, and public health communications. This service would probably be implemented by publishing time charts that indicate the periods during which these messages are permitted.

2. *A point-to-point data communications service.* This service would provide data message-switching between ground users by using the satellite relay capability. Point-to-point telegraphy between ATC centers, SAR fixed communications, and company fixed communications could be included as part of this service. At present, a variety of other networks are used to provide these types of communications. Appendix D presents an overview of these networks. The types of communications that could be conducted through the use of this service can be classified into a number of categories. The potential for implementing these types varies widely; thus some types would definitely be implemented before others. To obtain regulatory approval, it may be necessary to rank these in order of their potential for contributing to the safe and efficient movement of passengers and aircraft. The following list provides a ranking on this basis for the categories that may be candidates for off-peak data communications:

   a. Flight-dispatching coordination
   b. Aircraft trouble reporting and coordination of maintenance activities between ground facilities

c. Flight planning between points on ground (communication of weather, route planning, etc.)

d. In-flight information between points on ground (estimated times of arrival, rerouting, alternative airport, etc.)

e. Company business - administrative (crew schedules, baggage claims, etc.)

f. Company business - reservations and ticket sales

g. Point-to-point passenger communications (e.g., passenger at an airport sending ahead a "meet me" message)

3. *The electronic switching service.* This service would utilize only the capabilities of the AEROSAT ground segment to provide electronic switching among various domestic and international networks. For example, information received over the Aeronautical Fixed Telecommunications Network (AFTN) may be required by a company served by the ARINC network. The ASCC would provide the functions necessary to route this information from an AFTN facility onto the ARINC network. Included as part of this process would be certain functions necessary to ensure a compatible interconnection (e.g., code conversions and speed conversions). The types of information that would be exchanged by means of the service would be the same as those identified for the point-to-point data communications service.

4. *The network back-up service.* This service would use the capabilities of the space and ground segments to provide a voice and data communications back-up for other international networks, such as those identified in Appendix D. Increased network reliability or a need for system overload capability would be the reasons for introducing this service. Systems that currently utilize redundant circuits and alternative routing capabilities are probably the best candidates for this service since it can eliminate or reduce the cost burden of full-period redundancy.

The aspects of these services most important to the user will be cost and communication delay. A cost analysis using postulated tariff schedules will be required to determine how the cost will be levied (see Section 4.4). The communication delay associated with these services is a proper subject for investigation during the T&E program. A comparison of the delays experienced with the maximum delay times acceptable to the users will produce a primary measure of the merits of providing each service and the types of communications within each service.

4.3 AEROSAT SYSTEM ELEMENTS UTILIZED TO IMPLEMENT THE OFF-PEAK SERVICES CONCEPT

The connectivity utilized in the off-peak services concept is illustrated in Figure 14. The basic AEROSAT system elements, Mini-ASETS, conventional point-to-point circuits, and interfaces with other aviation-related networks are shown interconnected to provide several alternate routes through which

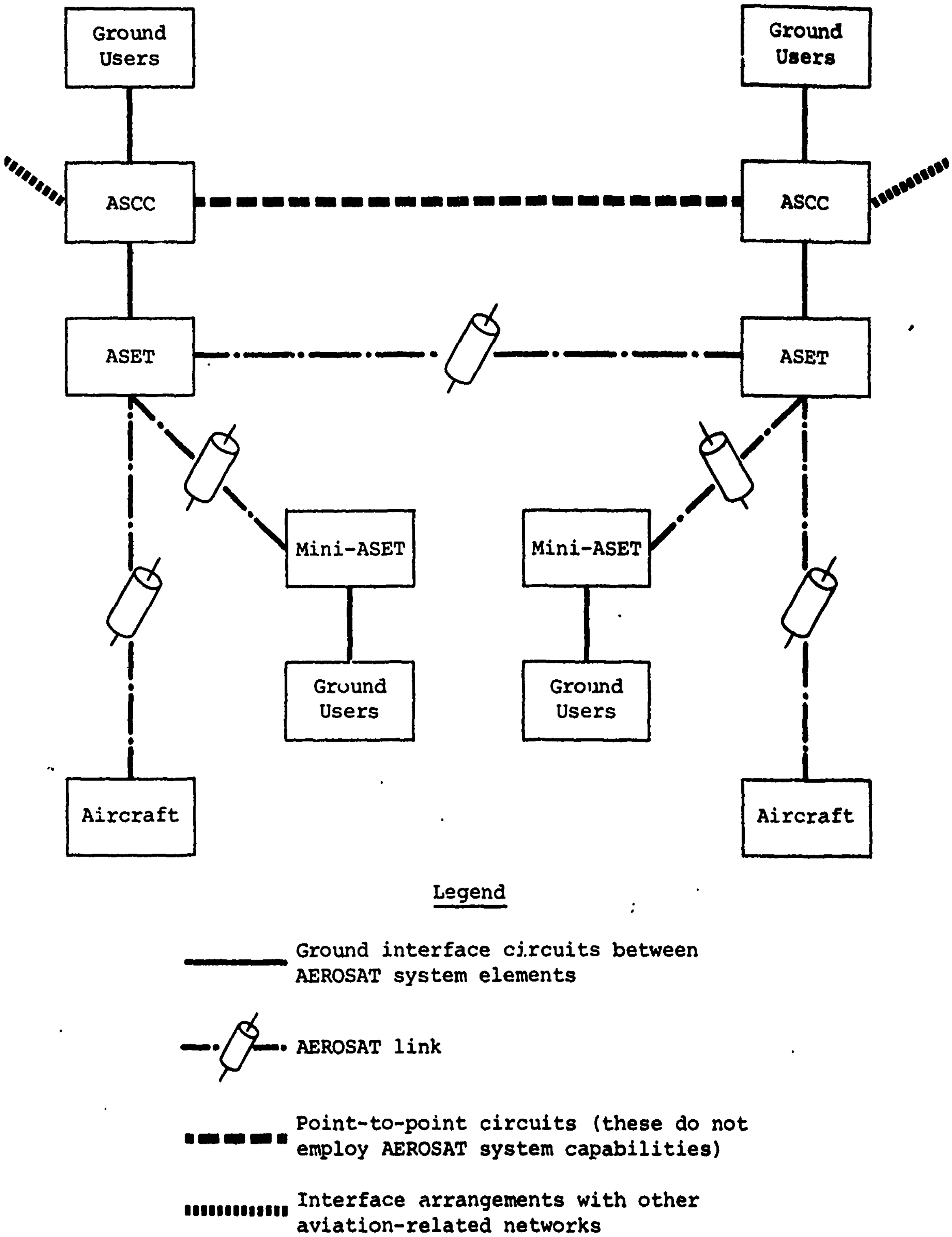


Figure 14. CONNECTIVITY OF THE OFF-PEAK SERVICES CONCEPT

both air-ground-air and point-to-point communications can be conducted. Three uses of the AEROSAT system elements are particularly important in achieving this connectivity:

1. Mini-ASET for point-to-point communications
2. ASCC for electronic intersystem switching
3. ASET C-Band/C-Band channels for point-to-point communications

The major considerations for using the system elements in these ways to provide the off-peak communications services identified in Section 4.2 are described in this section.

4.3.1 Use of Mini-ASET for Point-To-Point Communications

In addition to conducting air-ground-air communications, as discussed in Section 3.3, the Mini-ASET can be used to conduct point-to-point communications. By means of ASCC retransmissions (as explained in Section 3.3.2), these point-to-point communications would be routed over the same channels that are routinely used for air-ground-air communications. As the hub of all communications, the ASCC would be able to coordinate air-ground-air and point-to-point communications so that priority would always be given to requests for aeronautical mobile service.

Through this approach, a fixed service message can be originated by any ground user served by an ASCC or Mini-ASET and routed over channels normally used for aeronautical mobile communications to a distant ground user. A ground user initiates this process by making a request for a fixed communications service to the ASCC. If no request for aeronautical mobile service is in queue, the ASCC performs the necessary channel switching and indicates to the user that communication may begin. If the transmission is between a user served by an ASCC and a user served by a Mini-ASET, no ASCC retransmission is required. The ASCC simply selects a forward channel and a return channel and sends the message to, or receives the message from, a Mini-ASET. Upon receipt at either the ASCC or Mini-ASET, the message is checked for errors and a confirmation or request-for-repeat is returned to the message originator. The message is then routed to the intended user.

When communication between two Mini-ASETs is involved, an ASCC retransmission is conducted. As explained in Section 3.3.2, this retransmission can be effected on a concurrent or store-and-forward basis. In either case, the ASCC receives a message from a Mini-ASET, checks it for errors, and returns a confirmation or request-for-repeat to the message originator. When the message is received correctly, the ASCC then retransmits the message immediately, or at some later time, to the intended Mini-ASET. This Mini-ASET then checks the message for errors and returns a confirmation or request-for-repeat to the ASCC. When received correctly, the message is then routed to the intended user.

These capabilities of the Mini-ASET as a point-to-point communications facility will be relied upon greatly in providing the point-to-point data communications service and the network back-up service. For the point-to-point data communications service, routing will be achieved exactly as stated above. Since the network back-up service will also permit voice communications, the ASCC will be able to establish concurrent user-to-user connections to enable two-way voice conversations.

It should be noted that the Mini-ASET as a point-to-point facility will permit communication between any two ground users except where both ground users are served by ASCCs. These communications between two ASCC-served users can be conducted in two ways. In one, the message is routed from an ASCC to a Mini-ASET, then from a Mini-ASET to the other ASCC by means of channels normally used for aeronautical mobile communications. Thus the Mini-ASET, instead of an ASCC, performs the retransmission function. In the other way, the C-Band/C-Band coordination channels between ASETs are employed to route these messages. The use of these channels is discussed further in Section 4.3.3.

4.3.2 Use of ASCC for Electronic Intersystem Switching

To achieve the electronic switching service and the point-to-point data communication and network back-up services when one or more users are served by systems other than the AEROSAT system, the ASCC, in addition to its other requirements, must perform as an electronic intersystem switch. This is a result of the requirement that the AEROSAT system support total end-to-end communications. To do this, it must be able to convert, within certain limits, from one user's protocol to another to ensure that messages originated by users of one system can be received by users of another system. Were the ASCC not to provide this function, then a common protocol would have to be developed and imposed on all users of the AEROSAT system.

To operate as an electronic intersystem switch, the ASCC must be able to perform the following basic functions:

- Code and character conversion
- Speed conversion
- Error-protection regeneration
- Preamble reformatting

Code conversion is simply the processor's ability to translate between code sets -- e.g., between seven-level ASCC and six-level Baudot. Character conversion is the additional ability to convert a symbol in one alphabet to an associated symbol in another alphabet to convey the same meaning.

Speed conversion is necessary to provide interconnections when circuits employ different symbol rates or when the clocking pulses of two networks are not in synchronization.

Error-protection regeneration will be necessary whenever an interconnection is required between systems employing different error protection schemes. This is achieved by decoding the message according to one scheme,

making the necessary error detection or correction, and then recoding the message according to the other scheme.

Preamble reformatting is required to ensure system routing compatibility. Overhead bits (i.e., the preamble characters) are normally used to effect modem switching, signalling, channel switching, and other routing and processing functions. In one system a certain series of bits may indicate one function, while in another system the same series may indicate a different function. The ASCC would have to be able to reformat these preambles to prevent misinterpretation.

4.3.3 Use of ASET C-Band/C-Band Channels for Point-To-Point Communications

As discussed in Section 4.3.1, to obtain point-to-point communications between ground users served by ASCCs, the C-Band/C-Band satellite channels normally used for coordination will be required. When this type of communication routing is desired, the ASCC will first check the availability of these channels. If they are not being used for coordination of aeronautical mobile communications, the ASCC simply selects a pair of them for forward and return transmission and transmits the message via the satellite through a distant ASET to another ASCC. This ASCC then returns a confirmation or a request-for-repeat to the first ASCC. When the message is received correctly, it is routed to the intended user.

The use of these channels may be required as part of the communications associated with all of the off-peak communications services. For the low-priority air-ground-air communications service, C-Band/C-Band channels may be required when a user served by one ASCC has requested communication with an aircraft controlled by another ASCC. For the other services, these channels will be necessary to route information through two ASCCs.

4.4 POTENTIAL PROBLEMS ASSOCIATED WITH THE OFF-PEAK SERVICES CONCEPT

Even if it should prove to be operationally desirable and cost-effective to the aviation community, the implementation of the off-peak services concept is not a currently accepted feature of the agreed-upon AEROSAT system. Moreover, it is not currently permissible to transmit this form of communications on frequencies allocated to the aeronautical mobile service. Further investigation in two areas -- radio frequency regulation and system cost allocation -- will be necessary if the off-peak uses discussed in this chapter are to be permitted in an operational system. This section present discussions of these areas as they pertain to the implementation of an off-peak services concept.

4.4.1 Radio Frequency Regulation Associated With the Off-Peak Services Concept

At present, the International Telecommunication Union (ITU) Radio Regulations make it clear that aeronautical mobile frequencies may be used only for air-ground-air communications. The following excerpts from these regulations summarize the current international policy.

"Frequencies in any band allocated to the aeronautical mobile (R) service are reserved for communications between any aircraft and those aeronautical stations primarily concerned with the safety and regularity of flight along national or international civil air routes."

"Frequencies in any band allocated to the aeronautical mobile (OR) service are reserved for communications between any aircraft and aeronautical stations other than those primarily concerned with flight along national or international civil air routes."

"Administrations shall not permit public correspondence in the frequency bands allocated exclusively to the aeronautical mobile service, unless permitted by special aeronautical regulations adopted by a Conference of the Union to which all interested Members and Associate Members of the Union are invited. Such regulations shall recognize the absolute priority of safety and control messages."

The current regulations notwithstanding, the trend toward data communications and the subsequent automation of ground stations could provide the needed incentive for the authorized use of aeronautical mobile frequencies to provide off-peak communications services. In order to consider a revision in the current ITU Radio Regulations, three conditions would most likely have to be demonstrated:

1. The communications associated with the off-peak communications services can be conducted in complete coordination with aeronautical mobile communications so that full utilization of the frequencies assigned to the stations of the satellite system can be achieved.
2. The types of communications provided by the off-peak services concept are necessary or desirable for the safe and efficient movement of aircraft and aircraft passengers.
3. The introduction of the off-peak services concept will not degrade the quality of aeronautical mobile communications.

The T&E program can and should be used as a vehicle for producing the substantiation (or refutation) of the above conditions. The test areas suggested in Section 4.5 will indicate how the T&E program can be used for these purposes. Should the T&E program demonstrate the advantages of the off-peak services concept and should its adoption be desired by one or more authorities, then it would be necessary to request a change to the appropriate regulations at an appropriate World Administrative Radio Conference (WARC).

4.4.2 System Cost Allocation

The justification of the off-peak services concept on an economic basis is equally important as the solution to the problem of radio frequency regulation. Two aspects of this economic justification must be considered:

1. The best method of allocating costs to users of off-peak communications services on the basis of system usage and an equitable distribution of the services' nonrecurring implementation costs.

2. The potential unfair competition that may arise between the AEROSAT-system-provided communications services and similar services offered by other systems as a result of the unusual cost-allocation aspects associated with and giving advantage to the AEROSAT-provided services.

To resolve the cost-allocation and service-competition problems, it will be necessary to demonstrate that the off-peak services concept will provide benefits to the aviation industry at an equitable cost without causing a significant loss of revenue to systems providing similar services. Activities conducted during the T&E program should focus on collecting the data necessary for such demonstration:

- Equipment and administrative costs of providing off-peak services
- Kinds and quantities of communications conducted, on a per user basis
- Quality of communications, including message error rates and delay characteristics
- Analysis of alternative cost-allocation schemes

4.5 SUGGESTED TEST AREAS FOR THE OFF-PEAK SERVICES CONCEPT

To investigate and validate the potential merits of implementing an off-peak services concept, five areas of testing should be planned and conducted during the T&E program.

4.5.1 Concept Demonstration

Tests should be planned to demonstrate the AEROSAT system's ability to coordinate air-ground-air and point-to-point communications and to conduct both types of communications with appropriate priorities. As part of this testing, the problems associated with the implementation and operation of this concept should be identified. Information necessary to develop SARPS should also be obtained from this area of testing.

4.5.2 Communications Stimulation

During some portion of the T&E program, users should be asked to employ the AEROSAT system to conduct any communications that they believe might help them to perform their mission. Observation of the types and quantities of communications that result from this request will provide an indication of the increase in communications that might occur if an off-peak services concept were to be fully implemented as part of an operational system. This information will be used to determine the communications loading that may eventually be attributed to off-peak communications.

4.5.3 Communications Delay Data

For each off-peak communications service and for different message categories within each service, records should be maintained to show the delays that are incurred in conducting these communications. These delay data should be classified as access-control delay times, queuing delay times, and service delay times. The total delay time will, of course, be the sum of these. The data will produce the information needed to determine the value of providing off-peak services and the relative merits of providing various categories of off-peak communications.

4.5.4 Complementary Peaking Effects

The overriding reason for considering the off-peak services concept is that the off-peak communications services can advantageously be provided during periods when channels are not used for aeronautical mobile communications. The success of this concept will depend directly on the extent to which peaks in low-priority air-ground-air and point-to-point communications complement the peaks in aeronautical mobile communications. Data must be collected to determine how well these two types of communications can complement each other, with the recognition that aeronautical mobile communications have absolute priority over the other communications.

4.5.5 Intersystem Message Compatibility

The success of the ASCC as an electronic intersystem switch will depend on its ability to provide message-format compatibility among all intersystem users. During the T&E program, the requirements for achieving this compatibility should be identified.

CHAPTER FIVE

SUMMARY OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

During this study, communications concepts that should be considered for evaluation during the Aeronautical Satellite (AEROSAT) Test and Evaluation (T&E) program have been investigated. The work represents an initial investigation of the operational configurations that may be tested during the program, and it has been recognized from the outset that continuing re-evaluation of the results of this study will be necessary throughout the test planning stage of the program. Nevertheless, the study has considered and begun to clarify the following issues:

1. The more important fundamental combinations of communications services, operating modes and message types and characteristics that should be operationally tested during the T&E program.

2. The prominent technical and operational factors associated with the selection of a preferred operational concept.

3. Reasons for considering expanded uses of an AEROSAT system, in particular those applications associated with the Mini-ASET and off-peak services concepts.

4. Specific potential capabilities and applications of the Mini-ASET concept.

5. Potential applications and implementation of an off-peak services concept.

6. Potential problems associated with the expanded uses of an AEROSAT system, especially those associated with the use of the system for communications not technically defined as aeronautical mobile.

7. Operational tests to be conducted during the T&E program.

Seven basic operational concepts and two expanded uses for an AEROSAT system have been evaluated to determine the alternative communications services, operating modes and message types and characteristics that should be evaluated during the T&E program.

The seven basic concepts describe a number of possible methods for conducting conventional aeronautical mobile satellite communications. The air-ground-air communications services offered by these concepts range from voice-only communications with voice position reporting to voice and data communications with dependent and independent surveillance. The operating modes associated with these concepts range from a manual access-control system that calls for the use of channels on a contention basis to a fully-automatic and ordered access-control system. Together, these concepts suggest the more important areas for operational evaluation during the T&E program. Particular technical and operational factors and suggested tests associated with the implementation and evaluation of these concepts have been evaluated.

The two expanded uses for an AEROSAT -- the Mini-ASET concept and the off-peak services concept -- illustrate unconventional methods of utilizing an aeronautical satellite system. The Mini-ASET concept presents two methods for providing communications access to a satellite system in areas where it is undesirable, impractical or impossible to use conventional communication facilities. In one case, the Mini-ASET communicates with aircraft by means of direct satellite relays. In the other, indirect relays via an Aeronautical Satellite Communications Center are employed to provide the communications links between Mini-ASET and aircraft. Unfortunately, only the second of these methods is suitable for direct testing during the T&E program. A simulated configuration has been suggested as an indirect means for evaluating the first method. The application of these configurations for air traffic control, search and rescue, and company operational purposes was then evaluated. At the conclusion of the examination of this concept, some of the tests that should be conducted to demonstrate the use of the Mini-ASETs were identified.

During periods of low air-ground-air communications, the satellite system could potentially support additional types of communications. The off-peak services concept presented herein would permit the transfer of information between ground users and aircraft and among ground users in a manner that would not jeopardize the system's primary purpose of providing aeronautical mobile communications services. The potential services that could be offered through the implementation of this concept, the complex problems that would have to be solved if its implementation is to be permitted, and the tests that should be conducted to determine the concept's merits have been addressed.

With due regard to the preliminary status of the results of the present investigation and to the relation of the present investigation to the overall FAA test planning, the following recommendations are offered:

1. The FAA should proceed to define and approve a reasonable and well-organized set of practical operational concepts for long-term evaluation based on the seven concepts presented herein. By doing so, the FAA will provide program participants, or at least those associated with the U. S. portion of the program, clear direction as to the elements of operational test planning that can and should be pursued. It is important that the number of operational concepts to be evaluated not be excessively large so as to permit effective use of experimental time during the T&E program.

2. In order to test and evaluate the Mini-ASET effectively, research beyond that conducted in this study should be conducted to provide definitive results on the most desirable specific applications of the Mini-ASET. This research should include the use of in-depth survey techniques to develop case histories and other data on the nature of present communications problems and the requirements to be satisfied by the candidate solutions. From these efforts, it will be possible to determine more specifically the potential applications associated with the Mini-ASET concept.

3. Potentially, the full utilization of the capabilities of the AEROSAT system, and any subsequent operational system, may be achieved only through the adoption and implementation of an off-peak services concept. However, the current regulatory environment and certain economic unknowns cause the viability of this concept to be in question. It is therefore recommended that investigation be undertaken early in the T&E program to determine, in more quantitative terms, the potential for and desirability of the implementation of an off-peak services concept. This investigation would necessarily include the consideration of current radio frequency regulations, the projected regulatory environment, the economic benefits of the concept to users and the legality of implementing off-peak services on the basis of current and projected tariff regulations.

4. Given that the results obtained from the investigation recommended in (3) above are favorable, it would then be necessary to obtain interconnect arrangements with existing aviation-related networks in order to test and evaluate the technical and operational aspects of the off-peak services concept during the T&E program. It is therefore suggested that, contingent upon the results of the aforementioned investigation, work should be initiated to develop the technical groundwork for making these interconnections.

APPENDIX A

TERMINOLOGY

Air-Ground Access Control Technique - A method through which aircraft users gain access to satellite channels.

Calling at Random - A calling technique wherein the communications request is initiated at random and without any knowledge of the availability of the channel used to make the request.

Calling by Response to a Periodic Poll - A calling technique wherein the communications request is transmitted to the ground in response to a query from the ground. Since the request may be initiated by the user at random, there will almost always be a delay between the time the user makes the request and the time it is actually sent to the ground in response to a poll. On the average, this delay time will equal one-half the polling interval. (See Appendix C).

Calling Technique - An air-ground access control technique wherein aircraft users initiate short messages to indicate a desire to communicate and only begin conversation, or any other message transmission, after a channel assignment is received from the ground.

Channel Scanning - A ground-air access control technique in which aircraft receive supervisory and textual information by scanning across all, or a particular group of, communications channels.

Channel Switching - A method of handling traffic through a switching center, either from ground users or aircraft users, whereby a dedicated transmission path from sender to receiver is completed at the time of transmission. Contrast with "message switching" in which no such physical path is established.

Conversational Exchange - A type of information exchange wherein information is passed back and forth between users in a "listen-then-talk" manner as in a voice conversation.

Dedicated User Circuit - Any channel or combination of channels designated to be at the exclusive disposal of a given subscriber.

Dial Pulse - A current interruption in the DC loop of a calling telephone. It is produced by the breaking and making of the dial pulse contacts of a calling telephone when a digit is dialed. The loop current is interrupted once for each unit of value of the digit.

Ground-Air Access Control Technique - A method through which ground-originated traffic is properly delivered to the appropriate aircraft.

Inband Signaling - Signaling which utilizes frequencies within the voice or intelligence band of a channel.

Mark-Idle Channel Scanning - See Appendix B.

Message Switching - The technique of receiving a message, storing it until the proper outgoing line is available, and then retransmitting. No direct connection between the incoming and outgoing lines is set up as in channel switching.

Net Operation - Nets (netted operation) are ordered conferences whose participants have common information in needs or like functions to perform. Nets are characterized by adherence to standard formats. They are responsive to a common supervisor entitled the Net Controller (Net Control Stations) whose functions include permitting access to the net and maintaining circuit discipline.

One-Way Exchange - A type of information exchange wherein information is passed from sender to receiver without a returned response from the receiver.

Overhead Bit - A bit other than an information bit. Any bit utilized by the system to organize, route, identify, synchronize or error-protect a message transmission.

Poll-and-Response Exchange - See Appendix C.

Seizure After Listening - A seizure technique wherein the aircraft user seizes a return channel after making a determination of the availability of the return channel by listening on the forward channel.

Seizure After Observing Channel Status Indicator - A seizure technique wherein the aircraft user seizes a return channel after making a determination of the availability of the return channel on the basis of channel status information received from the ground over the forward channel.

Seizure at Random - A seizure technique wherein an aircraft user has no apriori knowledge of the status of a channel and thus seizes a return channel at random and immediately begins a message transmission.

Seizure Technique - An air-ground access control technique wherein an aircraft user seizes a return channel on the basis of channel status information available to him on board and immediately begins a conversation, or any other message transmission.

Semi-Permanent Channel Assignment - A ground-air access control technique whereby each aircraft is assigned a particular communications channel to monitor continuously for a relatively long period of time.

Supervisory Channel - A communications channel whose primary function is to indicate the various operating states of a system or subsystem.

Supervisory Channel Assignment - A ground-air access control technique wherein all desires-to-communicate and the subsequent assignment-information are transferred over a supervisory channel. All aircraft monitor the supervisory channel, are addressed over this channel, and are told over which channel a message is coming or over which channel a message may be transmitted.

Two-Way Independent Exchange - A type of information exchange wherein the information transferred in one direction is time independent of the information transferred in the other direction even though, from an intelligence sense, the exchanges may be related.

Working Channel - A channel used to conduct information exchanges. Contrast to a "Supervisory Channel" in which only system-status intelligence is exchanged.

APPENDIX B

MARK-IDLE CHANNEL SCANNING PROTOCOL

Mark-idle channel scanning protocol describes a ground-air access control technique capable of assigning channels on a demand-assign basis through the use of aircraft avionics scanning receivers. It represents an attempt to minimize the header and channel dwell times normally associated with channel scanning in systems using frequency division multiple access (FDMA). It has been proposed as part of two basic operational concepts described in Chapter Two of this report.

In this appendix, the theory of operation of this technique is discussed briefly.

When one or more unused satellite channels are available in a particular area, one is automatically selected at the ASCC. The ASCC then transmits an idle tone on that channel, thus marking it idle. All aircraft avionics units scan across each channel in their complement, detect the presence of the idle tone and select that channel for monitoring.

If the avionics is resting on an idle channel when the aircraft user goes "off-hook" to originate a call, it transmits a guard tone and a connect tone. The receipt of the connect tone causes the ASCC to remove the idle tone from the channel and to mark a new channel idle. As a result, all avionics now proceed to search for the new marked idle channel, except that the avionics originating the call is prevented from searching while transmitting. The ASCC now transmits a seize tone and when this tone is removed, the avionics automatically identifies itself by sending an address signal. When identification is complete, the handset is unmuted and a dial tone is received from the ASCC. Once the dial tone is received from the ASCC, dialing can begin. After dialing is completed and the called party answers, conversation may follow.

When the aircraft user goes "on-hook" after the call is completed, the avionics transmits a disconnect signal indicating that the user has vacated the channel. The avionics is then unlatched and it proceeds to scan for the new idle channel in preparation for the next call. The ASCC returns the former channel to the pool for future idle marking.

When a call is received at the ASCC and identified by the control equipment as being for an aircraft, it is fed to the marked-idle channel. The ASCC then replaces the idle tone with a seize tone and marks a different channel idle. The avionic units previously locked on the channel by the idle tone now use the seize tone as a latch. The ASCC then transmits the address of the desired mobile.

After correctly receiving its address, the avionic unit transmits an acknowledge signal to the ASCC indicating reception of the address. The ASCC then sends a ringing signal to actuate a ringing circuit in the avionics, alerting the aircraft user of an incoming call. When the aircraft user goes "off-hook" in answer to the incoming call, the avionic unit transmits the connect tone. The ASCC then removes the ringing signal and converstaion may begin.

After the call is completed and the handset is hung up, the avionics unit transmits a disconnect signal. This signal informs the ASCC that the channel has been vacated. The avionics unit is then unlatched and channel scanning begins as previously described.

If a wrong number is received for any of the digits in the aircraft's address, a mismatch occurs. This mismatch causes all avionic units except the one addressed to search for the new marked-idle channel.

If a call to an aircraft is left unanswered for a specified period of time (for example, 45 seconds), the seize tone is removed from the channel and the avionics unit begins its search for the new marked-idle channel.

If an aircraft user goes "off-hook" while the avionics is not locked on an idle channel or while it is receiving a signal from the base station, the control display unit causes the handset to remain mute so that a call cannot be initiated. If the channel is idle at the time of "off-hook" but (a) the idle tone is lost before a connect tone is transmitted (channel seized by another aircraft) or (b) the idle tone is lost while the connect tone is being transmitted (aircraft transmission not received by ASCC), the handset would again remain mute. The call attempt is thus blocked, and the avionic unit begins to search for a new idle channel.

APPENDIX C

POLL-AND-RESPONSE ACCESS CONTROL DISCIPLINE

Poll-and-response data channels have been proposed, in various forms, for several of the basic operational concepts described in Chapter Two of this report. The access control discipline offered by these channel configurations has the potential of providing a great deal of system flexibility. This appendix discusses many of the factors that should be considered in order to take full advantage of this flexibility given a particular set of system requirements.

Poll-and-response access control discipline consists of polling on pre-assigned data channels, link control functions, and link discipline functions. Each set of avionics continuously monitors a pre-assigned data channel. The controller establishes a polling sequence as aircraft enter the system. Each aircraft is in turn polled at a prescribed rate. Upon detecting its identification code, the avionics responds with a transmission to the ground on a paired return channel or a return channel assigned by the polling message. Link control functions must be included in the data-link structure to accomplish the following:

- Determine the beginnings and ends of messages
- Allow logical information processing
- Establish and maintain message accountability
- Provide error protection
- Provide a method for acknowledging the receipt of air- and ground-initiated messages
- Provide for signal acquisition and bit and character synchronization

Link discipline functions provide the operating philosophy framework of the data link. These functions prescribe:

- Polling rates and sequence
- Message routing
- Transmission timing parameters such as propagation times, data transmission rates, and doppler correction frequencies

In specifying these functions, one must be aware of their combined effect on channel requirements. In the following paragraphs, many of the considerations that must be investigated during the T&E program to determine the effect of link control and link discipline on channel capacity are described.

The sizing of a poll and response data channel subsystem is based on the deterministic, rather than probabilistic, specification of system parameters. It requires the determination of values for (1) polling rate, (2) communications overhead, and (3) block length.

Polling Rate

Five kinds of polls must be considered: (1) surveillance and routine message, (2) time-critical message, (3) normal entry, (4) "do-you-want-to enter?" and (5) "do-you-have-an-emergency?". Surveillance and routine message polls provide the vehicle for conducting system or subsystem supervision, surveillance gating and data transfer, and routine air-ground channel access. Time-critical message polls would be initiated immediately each time a ground-initiated, time-critical message occurred. The routine polling sequence would be interrupted, the time-critical message poll would be transmitted, and, upon completion of this poll, routine polling would resume. Normal entry polls are required to allow the ground station sufficient reception time to acquire the entering aircraft's carrier signal, synchronize bits, and then calculate and store the corrected doppler frequency. This frequency is recalled each time the aircraft is polled to reduce the time required to acquire the aircraft's transmitted carrier. One normal entry poll per aircraft entry is required. "Do-you-want to enter?" polls are interspersed with other polls to allow random-entry aricraft to acknowledge their presence. "Do you have an emergency?" polls are also interspersed to allow aircraft to alert the ground of an emergency nearly instantaneously.

The polling rate must be high enough to meet the following conditions:

- All aircraft are polled at a prescribed rate (e.g. 30,60,90 or 120 seconds). The selection of the prescribed rate for each aircraft may consider the aircraft's speed and location and the pilot's probable need for and frequency of communication, or the rate may be predetermined for all aircraft or particular classes of aircraft (e.g. wide-body, supersonic, and conventional jet).

- Sufficient additional polls are generated for time-critical ground-to-air messages that cannot be delayed for the normal polling cycle. These time-critical messages will be related to the separation of aircraft.

- Sufficient additional polls are provided to facilitate entry into the system of aircraft that are anticipated by ATC (i.e., known aircraft entering the AEROSAT coverage area).

- Sufficient additional polls are provided to offer emergency communications rapid access to the system.

The polling rate to satisfy the above criteria and serve A aircraft is given by:

$$PPS = P_N(A) + P_{TC}(A) + P_{PE}(A) + P_{UE} + P_{EC} + MPM$$

where

PPS = polls per second

A = number of aircraft (IAC)

$P_N(A)$ = the normal communications polling rate

$P_{TC}(A)$ = the time-critical message polling rate

$P_{PE}(A)$ = the polling rate for planned system entries = $\frac{A}{AFD}$

AFD = flight duration (in seconds)

P_{UE} = the polling rate for unanticipated aircraft system entries

P_{EC} = the polling rate for emergency communications

MPM = the rate of occurrence of milti-poll messages

Values of $P_{TC}(A)$ are computed by summing the frequency of occurrence of conflict-solving ATC messages that are expected to be exchanged by the poll-and-response subsystem. Conflict-solving ATC messages include Route Control, Altitude Control, Clearance Control, Speed Control, Route/Speed Information, and Essential Traffic Information.

Multi-poll messages are messages that are too long to be transmitted within the standard block of time and yet are urgent enough that they cannot be spread over several regularly scheduled polls. Additional block time during a single poll must therefore be allocated to allow these messages to be exchanged. This is equivalent to polling the same aircraft two or more times in succession, thus the term multi-poll messages. The specification of this equivalent polling rate for multi-poll messages (MPM) is dependent on the message block length, and their occurrences may be associated with any of the other five types of message polls.

Communications Overhead

The components of communications overhead differ for message data channels and supervisory data channels and for forward and return channels. Moreover, normal entry, random entry, and emergency-message formats are classified as overhead. The foward-data overhead for all of these categories is considered to be the same; but the return-data overheads differ among message data, supervisory data, and nonroutine (normal entry, random entry, emergency) data. The requirements in each of these categories are summarized below.

1. Overhead Requirements for Forward-Channel Messages -- It has been presumed that aircraft would continuously monitor forward data channels to avoid the lengthy acquisition requirements associated with initial airborne carrier acquisition and bit synchronizations (approximately one second of transmission time). For continuous channel operation, 18 overhead characters per message are required to synchronize, identify, route, acknowledge, and error-protect forward data messages. The components of this overhead are illustrated in Table C-1. At 1200 bits/second, the overhead load for forward data is 0.12 second per message poll using this overhead structure.

TABLE C-1
FORWARD DATA CHANNEL OVERHEAD REQUIREMENT

Component	Number of Characters
Character Sync	2
Start of Heading	1
Mode	1
Address	7
Technical Acknowledgement	1
Label	2
Start of Text	1
Suffix	1
Block Check Sequence	2
Total	18

2. Overhead Requirement for Return Message Data -- In addition to the basic message overhead requirement defined in Table C-1 a transmission time of 80 milliseconds must be allocated for each return message to provide a propagation time-differential guard and an acquisition preamble. The guard (40 msec) is necessary to preclude two aircraft -- one at a satellite subpoint and the other at a coverage boundary -- from producing interfering signals at the satellite due to the different path delays involved. The preamble (40 msec) allows the ground station to acquire carrier and bit

synchronization when the corrected doppler frequency is known. At 1200 bits/second, this amounts to a total return message data overhead of 30 characters, or an overhead load of 0.2 second per return message.

3. Overhead Requirement for Return Supervisory Data -- Return supervisory data overhead consists of the 18-character basic message overhead, the 80-millisecond guard and preamble overhead, and a six-character supervisory message overhead to allow transmission of certain special data such as altitude data for independent surveillance. Supervisory data overhead on return channels thus totals 36 characters, 0.24 second per message, for a transmission rate of 1200 bits/second.

4. Overhead Requirement for Return Non-Routine Data -- The special problem created by the return transmission on non-routine data is that the ground station has not yet calculated and stored the corrected doppler frequency for the aircraft. For these cases, a 40-millisecond guard and a 300-millisecond carrier acquisition and bit synchronizati[illegible] preamble are required in addition to the basic message overhead of 1[illegible] characters. A total of 69 characters, 0.46 second at 1200 bits/second, is required for each return non-routine message.

Block Length

As a minimum, the block length must be designed so that the average throughput load can be accommodated. This dictates that the following inequality must be satisfied:

$$\frac{(\text{Channel Loading}) \times (\text{Data Rate})}{\text{Polling Rate}} + (\text{Overhead}) \leq (\text{Block Length})$$

where

channel loading is the true message loading in erlangs

data rate is in bits/second

polling rate is in polls/second

block length is in bits

overhead is in bits

In addition, however, one other criterion, a trade-off, should be considered. It is desirous that a high number of message occurrences have a message length less than or equal to the block length. This assures that a great majority of the messages are transmitted during one poll or response. For some cases, this implies that the block length would have to be a great deal larger than [illegible] minimum as specified above. Larger-than-minmum block

lengths result in poor utilization in the long term since the average message length would be much smaller than the block length -- thus the trade-off.

The block-length requirement is highly dependent on the average data throughput requirements (bits/second) and the anticipated lengths of messages. For this reason, general block-length decisions cannot be presented. It can be concluded that block length must consider guard and preamble times, message overhead lengths, and average as well as maximum message lengths. Typically, the block length for return data channels may be selected to be two or three times longer than the forward block length in order to maximize the resources of each. This implies that in the poll-and-response data subsystems one forward data channel may be paired with two or three return data channels.

Calculation of Channel Requirements

Once values for the polling rate and block length have been determined, the number of forward and return polling channels can be computed individually with the following relationship:

$$N_{ch} = \text{Int}\left[\frac{PPS \times MBL}{R}\right]$$

where

N_{ch} = number of required polling channels

PPS = polls per second as determined previously

MBL = the message block length in bits

R = the per- channeldata rate in bits per second

INT = symbol used to indicate that N_{ch} must be the smallest integer that is greater that the quantity in brackets

APPENDIX D

INTERNATIONAL AVIATION-RELATED NETWORKS

In this Appendix, some of the international aviation-related networks that might interface with the AEROSAT system as part of the off-peak services concept discussed in Chapter Four of this report are identified.

Aeronautical Fixed Telecommunications Network (AFTN)

The AFTN is an integrated world-wide system of aeronautical fixed circuits provided, as part of the Aeronautical Fixed Service, for the exchange of messages between aeronautical fixed stations within the network. As part of the International Aeronautical Telecommunications Service, it is intended primarily for the exchange of messages concerning the safety of air navigation and the regular, efficient, and economical operation of air services. The AFTN provides communications service for international aircraft movements, administrative messages and meteorological data among ICAO nations. Each ICAO member nation has certain responsibilities to provide service to the AFTN.

The following categories of message are handled by the AFTN on a specified priority basis:

- Distress messages and distress traffic
- Urgency messages
- Flight safety messages
- Meteorological messages
- Flight regularity messages
- Aeronautical administrative messages
- NOTAM - Class I distribution
- Reservation messages
- General aircraft operating agency messages
- Service messages

Additional information on the structure of the AFTN and the messages handled by the AFTN may be obtained from the following sources:

- Annex 10 to the Convention on International Civil Aviation, Volumes I and II
- ICAO Air Navigation Plans

- FAA Communications System Description (1973), Report No. FAA-RD-73-36, Computer Sciences Corporation, Falls Church, Virginia 22046, Final Report, February 1973.

Societe Internationale de Telecommunications Aeronautiques (SITA)

SITA was founded in 1949 as an international and cooperative society of airlines capable of pooling each company's telecommunications facilities for the benefit of all. In 1949, SITA was composed of 11 member companies and at the end of its first year was operating in 19 countries. Today, it consists of some 173 international airlines and its network almost literally covers the globe.

The aim of the Society is the study, creation, acquisition, utilization and operation in all countries of the means necessary for the transmission and, where required, the processing of all categories of information connected with the operation of the air transport organizations of its members, with the exception, however, of messages of a private character and addressed to the public.

The SITA network has been implemented by the airlines for the transmission of messages other than those relating to flight safety. It has been developed in full cooperation with that of the Aeronautical Fixed Telecommunications Network (AFTN) along parallel lines, with a view to complementing the AFTN.

The SITA network includes nine computerized switching centers: in Amsterdam, Brussels, Frankfort, Hong Kong, London, Madrid, New York, Paris and Rome. These are linked by 4800 bps synchronous, full duplex, leased lines. Each center is connected to at least two other centers. Collectively this is known as the "High Level Network (HLN)". Connected to these nine nodes, directly or indirectly, are about 7,000 terminals. Most are teletypewriter, but there is also a variety of computers doing administrative and reservation work for SITA member airlines. The system encompasses about 250 leased communications channels and employs a variety of communication media ranging from human messengers to space satellites to accomplish its connectivity.

Basically, the SITA net handles two kinds of traffic. The bulk of it consists of 50-75 baud teletypewriter messages, averaging 200 characters/message. This "Class B" traffic involves administrative matters like lost baggage, passenger reservations, and flight servicing information. It also includes messages transmitted between and/or among the reservations computers of different member airlines. "Class A" messages are relatively short inquiry-response type communications between a reservations agent operating a crt terminal, and his airline's central reservations computer. A typical Class A inquiry is 18 characters long and the response is 100 characters.

Additional information on the organization of SITA and its network can be obtained from the following sources:

- S.i.t.a. Monograph, the s.i.t.a. Story, La s.i.t.a. et son histoire, J. Glories, Societe Internationale de Telecommunications Aeronautiques.
- SITA: Rating a Packet-Switched Network, Phil Hirsch, Communications Editor, Datamation, March 1974.

Corporacion Centroamericana de Servicios de Navegacion Aerea (COCESNA)

COCESNA is a quasi-government organization established by the five Central American States (Guatemala, Honduras, El Salvador, Nicaragua, and Costa Rica) to provide aeronautical fixed, aeronautical mobile, aeronautical navigation, and air traffic control services throughout Central America. In fulfillment of their aeronautical fixed function, COCESNA operates the Tegucigalpa terminal of the AFTN circuit connected to the U. S. FAA AFTN switch in Kansas City and a network comprising VHF link facilities interconnecting the Central American capital cities (Guatemala City, Tegucigalpa, San Salvador, Managua, San Jose) and some additional major city locations such as San Pedro Sula and Belize.

COCESNA is a product of a regional movement for Economic Integration of Central America, supported by the Alliance for Progress, and it came into being in December 1961.

Aeronautical Radio, Inc. (ARINC)

ARINC exists to serve the telecommunications of the air transport industry. On a not-for-profit basis, it designs, provides, and manages the telecommunications systems the industry needs to provide safe, regular, and economical operations. The scheduled airlines of the United States are the principal customers of the company and its principal stockholders. Its services, however, are extended to all aircraft operators, large and small, U. S. and foreign, scheduled and supplemental, business, private and government.

In its role as the communications company for the air transport industry, ARINC provides many services including air/ground communications for air carrier operational control, the provision and management of point-to-point communication facilities, and a message switching system. This latter service, ARINC's Electronic Switching System (ESS), is the largest private message switching and processing system in existence. It serves approximately 200 users representing substantially all U. S. and most foreign airlines including supplementary and commuter air carriers. Its principal function is to serve as the universal interface between the many airlines systems, foreign and domestic, which vary widely in characteristics and communications capabilities. In this regard code and/or speed conversion is accomplished automatically based on the requirements of its users. International access to ESS is achieved in several ways. Many foreign flag carriers have direct processor-to-processor interconnection links. Others are served through the ARINC common interconnection with the SITA computer switching center in New York which in turn provides worldwide access to their users. In addition, ARINC presently provides a communication

interface arrangement with AFTN and direct ESS common use facilities to Anchorage, Bogota, Havana, Hong Kong, Honolulu, Kinston, Mexico City, Pago Pago, San Juan and Tegucigalpa. ESS also serves as the vehicle through which messages copies by ARINC's air/ground operators are delivered to the using airlines.

International Aeradio, Ltd. (AERADIO)

AERADIO is a private international enterprise whose diversified operations include not only air-ground and point-to-point services in various countries around the world, but also the manufacture of electronic equipment and communications consoles, sales of aviation and communications equipment, public and commercial communications, various kinds of aviation ground services and printing and publishing. Its headquarters are in London, England.

Individual Airlines

In addition to the shared-user systems discussed above, many airlines operate international telecommunications circuits to satisfy peculiar needs of their international operations and to supplement the services offered by the share-user systems. These networks are normally interconnected with shared-user systems at one or more station locations, therefore providing a world-wide message-delivery capability. For instance, Pan American has a world-wide teletype network that integrates company-operated circuits with circuits provided by other agencies and interconnects with ARINC's ESS. Transworld Airlines, American Airlines and British Airways have similar networks.

ATS Direct Speech Circuits

These international circuits provide a direct speech capability between contiguous Air Traffic Service (ATS) control centers and between such other centers as are necessary to efficiently meet specific operational requirements. They comprise a portion of the international Aeronautical Fixed Service, but they are distinctly different from the circuits of the AFTN. While the primary intent of these circuits is to provide rapid-access controller-to-controller voice communications, they are utilized for the exchange of ATS and other messages.